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FIELD TESTS OF THE DIFFERENTIAL REACTION OF WHEAT VARIETIES TO ROOT ROT[1]

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The annual reduction in yield of wheat in Western Canada from the root-rotting fungi *Helminthosporium sativum* P. K. & B., *Ophiobolus graminis* Sacc., and *Fusarium* spp., presents plant pathologists and plant breeders with an important and difficult problem to solve. It is also true that unless the symptoms of these diseases are pronounced in the field, many wheat growers, as well as others, often minimize or entirely overlook the actual damage present. Certain crop sequences and cultural practices have been found very valuable in reducing the loss from root rots, but as these measures are not always entirely effective under all conditions it is generally agreed that a combination of greater varietal resistance in conjunction with the recommended cultural practices would offer the best possible solution of the problem. However, in securing varieties having greater resistance, we are at once faced with the fact that none of those grown in Western Canada are immune, and all are more or less susceptible to the pathogens mentioned. Moreover, in subjecting the varieties to a resistance test under field conditions we must recognize racial differences in virulence of the pathogens, and allow for the effect of reaction to climatic and other environmental soil factors on both pathogen and host. Of these, the effect of drought in obscuring the real disease reaction of the plant is one of the most important difficulties encountered.

The purpose of this paper is to present some of the data already obtained in tests for varietal resistance to the root-rotting fungi and to discuss related problems based on observations during 13 years.

MATERIALS AND METHODS

The plantings were made at Edmonton on a black loam in which root rots are known to develop well. The rows were 12 feet in length, 6 inches apart, and were replicated 4 times along a range 180 feet in length. When the study was begun in 1929, separate tests for varietal resistance to *O. graminis*, *H. sativum*, and *F. culmorum* W. G. Sm., were attempted by means of artificially infesting fallowed soil with the pathogens. However,

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as practically no infection resulted in the case of *O. graminis*, and often too severe seedling mortality in the cases of *H. sativum* and *F. culmorum*. these attempts were abandoned in 1932, and the method of natural soil infestation of all three pathogens mentioned, as favoured by continuous cropping to wheat, adopted. Two methods of artificially infesting the seed bed with *O. graminis* were used, namely, inoculum grown on sterilized oat hulls *(a)* incorporated with the soil before seeding, and *(b)* added with the seed. These two methods were also used in the case of *H. sativum* and *F. culmorum*, and, in addition, the technique of adding a spore suspension to the seed was employed. However, with the naturally infested seed-bed method, it was not until 1937 that a satisfactorily effective level of infestation was reached, and, therefore, all the work prior to this date was essentially of an exploratory nature, and the details are not included in this report. The infection rating data presented in this paper are indicative of the root-rot complex as caused by the various pathogens in a naturally infested soil.

One hundred seeds per 12-foot row were planted, with a belt seeder at a depth of 2 inches. Marquis wheat was planted every tenth row as a guide in estimating the amount of heterogeneity in the experimental area. The planting dates varied, but the mean date was about May 1. Notes were taken within 10 days prior to maturity by cutting crowns longitudinally and estimating disease severity on a percentage basis according to the relative degree of lesioning present in the crown tissue, and by an examination of the lesioning present in other parts of the root system, including the primary and secondary roots and the subcoronal internode. That is to say, the identification of inherent resistance was based wholly on actual disease symptoms, and not on the yielding ability of the variety. Obviously the latter quality would include many factors other than disease resistance. Since the method indicated of securing data is unavoidably somewhat qualitative, and based on personal judgment, it is necessary that the same observer take the notes each year.

There are various opinions as to the best way of estimating disease severity by the examination method (3). Although 11 classes of infection, varying from 0–10, were used in this study, a smaller number of classes would also give good comparative results. The number of plants to be observed from each plot, and the question of using the mode or the mean of the infection-classes are also moot points.

The importance of the factor of different dates of maturing of the varieties was appreciated, and experiments designed to accentuate the importance of this point are included.

EXPERIMENTAL RESULTS

A. Reaction of Wheat Varieties to Root Rots

Out of a total of 148 varieties and selections of spring-habit wheat tested for resistance from 1929 to 1941, the results from only 80, which

are listed with the infection ratings in Table 1, are given in this report. The others, which were discontinued by 1937, because they seemed to have no appreciable resistance, are listed below:

Bobs (Wylers)
Calcutta D_2B
Calcutta O-929-B
Ceres (Brandon)
Ceres (U. of A.)
C-25-13.5 (Brandon)
C-25-145.2 (Brandon)
C-25-85.1 (Brandon)
C-25-424.6 (Brandon)
C-26-12.3 (Brandon)
C-26-36 (Brandon)
C-26-44.7 (Brandon)
C-26-48.2 (Brandon)
C-26-58.2 (Brandon)
C-26-59.2 (Brandon)
C-26-153.15 (Brandon)
C-26-387.42 (Brandon)
C-26-703.7 (Brandon)
Crown × Prelude 932A
Duchess (Ott. 933)
Early Triumph
Forward
Garnet (Brandon)
H-44-24 × Marquis C.T. 127
Heines Kolben
Hope (U. of A.)
Hope—N.D. (Dickinson)
Hope—N.D. (Mandan)
Horning's grüne Dame
Huron (Cap Rouge)
I-28-61 U. of A.
Janetzke's
Khapli
Kitchener (Wheeler)
Kota (673)
Kota × Ruby II-19-19
Kubanka
Lohmann's galizischer Kolben
Manscholt's van Hock
Marquillo
Marquillo × Kanred
Marquis (McKay)
Marquis (Parker)
Marquis (Criddle)
Marquis (Brandon)
Marquis (Ott. 15)
Marquis × Kanred II-17-4
Marquis × Kanred B_9-14
Marquis × Iumillo II-15-43
Marquis × Iumillo II-15-51
Marquis × Iumillo II-15-54
Marquis × Prelude 928E
Pentad (Winnipeg)
Quality
Quality A
Red Fife (Sask. 73)
Red Fife × Downy Riga 642A
Red Indian × Common Emmer 45B
Red Quality A
Red Quality C
Reward (Ott. 928)
Reward (Brandon)
Ruben
Strube's roter Schlanstedter
Svalof's Diamant
Szekacs
Topaz
Vernal.

TABLE 1.—DISEASE RATING OF VARIETIES AND SELECTIONS OF WHEAT USED IN FIELD STUDIES OF RESISTANCE TO ROOT-ROTTING FUNGI FOR 1937, 1938, 1939, AND 1941

No.	Variety*	Disease rating				No.	Variety*	Disease rating			
		1937	1938	1939	1941			1937	1938	1939	1941
		%	%	%	%			%	%	%	%
7	Acme	53	29	34	43	1	Kubanka Ott. 37	56	30	31	34
56	Admiral Yellow × Early Sonora	61	36	28	43	12	Little Club	32	27	31	39
33	Alberta 3	68	47	34	44	38	Major	50	36	28	41
57	Apex	64	47	35	45	10†	Marquis U. of A.	54	40	33	43
8	Arnautka	55	35	30	40	53	Marquis × Kanred B_2-5	52	40	29	45
43	Aurora	62	27	31	42	78	Marquis × Iumillo II-15-55	55	39	28	39
58	Axminster	49	36	30	41	46	Master	70	49	37	41
62	Bishop	52	41	32	48	48	Minburn	46	38	35	43
65	Blue Ribbon	38	31	31	39	6	Mindum	53	34	37	43
39	Brownie	*61	35	44	46	68	McMurachy's C.T. 901	—	35	29	37
82	Caesium	41	33	19	44	32	O.A.C. 35	50	31	28	34
16	Canus	37	41	24	41	4	Peliss	47	29	29	38
17	Ceres	53	47	30	48	5	Pentad	59	39	31	45
66	Ceres × (Hope × Florence) C.T. 801	—	39	29	33	55	Pentad × Marquis C.T. 120	67	49	40	52
72	Ceres × Reward C.T. 215	—	—	33	—	84	Perages	26	15	20	27
31	Chelsea	56	37	33	48	35	Pioneer Ott. 195	52	36	27	42
45	Crown	55	38	40	36	64	Piper	43	38	37	44
67	Crown × Prelude O-940-A	68	49	38	45	23	Prelude Ott. 135	57	47	29	44
79	Double Cross (825.2)	46	33	26	43	29	Preston	52	33	22	40
71	Downy Riga × Calcutta 553A	72	47	32	46	47	Producer 45F	39	37	32	40
74	Early Prolific	51	37	32	42	34	Prospector	65	43	36	46
63	Early Red Fife Ott. 16	44	35	38	42	76	Pusa	68	36	26	54
44	Early Russian Ott. 40	56	40	37	44	15	Red Bobs 222	64	45	35	49
14	Garnet Ott. 652	58	36	30	45	22	Red Fife	30	29	24	39
75	Golden	50	40	28	41	49	Red Fife × Smooth Spelt 686A	46	40	32	43
28	H-44-24	69	44	25	40	41	Red Indian × Common Emmer Ott. 434	45	22	29	41
89	H-44-25 × Double Cross × Marquis C.T. 303	68	40	32	45	73	Red Russian	53	36	34	39
87	H-44-24 × Double Cross × Marquis C.T. 305	66	30	27	41	26	Renfrew	47	40	25	41
85	H-44-24 × Reward C.T. 118	55	34	29	38	69	Renown	70	47	34	42
86	H-44-24 × Reward C.T. 108	74	42	34	46	13	Reward U. of A.	60	41	33	50
27	Hope	63	37	24	43	19	Ruby Ott. 623	62	35	23	40
88	Hope × Reward C.T. 207	76	42	25	43	11	Speltz-Marz	65	35	32	43
21	Huron Ott. 3	41	34	23	42	59	Supreme	57	49	31	47
81	I-28-46 U. of A.	56	42	25	42	36	Swedish	31	36	35	44
2	Iumillo	62	40	23	38	61	Swedish O-880-D	47	48	38	45
3	Kahla	48	30	28	40	37	Tartan	36	30	29	41
24	Kitchener	56	31	27	38	83	Thatcher	69	46	26	42
25	Kota	44	30	19	37	18	White Fife Ott. 11	30	30	27	40
54	Kota × Ruby II-19-18	43	49	37	44	77	White Head	47	30	31	42
						51	White Russian D	42	28	24	33
						52	Yellow Fife × Omega Gehun Ott. 482B	63	49	31	42

† Marquis used as control every tenth row.

* The numbers opposite the varieties designate them in Tables 2, 4, 5, and 6.

The infection data, as based on readings on 20 plants per row and 4 replicates, are summarized in Table 2 for the seasons 1937, 1938, 1939, and 1941. Data for 1940 were not secured. In the table the variety number appears opposite the observed percentage infection ratings as found for each year. It will be noted that the range of infection ratings in 1937 was much wider than in the other three seasons, and that the degree

TABLE 2.—THE DISEASE RATING IN PER CENT OF 80 VARIETIES AND SELECTIONS OF WHEAT* TO ROOT-ROTTING FUNGI UNDER FIELD CONDITIONS. THE VARIETIES ARE GROUPED ACCORDING TO AVERAGE INFECTION RATING DURING EACH OF FOUR YEARS OF TEST.

%	1937	1938	1939	1941
19				
22		41	A 25 82	
23			A 29	
24			2 19 21	
25		A	16 22 27 51	
26			26 28 81 85	
27		12 43	B 20 76 79 83	
28		51	18 24 35 87	
29		4 7 22	3 32 38 42 56 75 78	
30	18 22	1 3 18 25 37 77 87	4 23 37 41 53 66 68 85	
31	36	24 32 65	8 14 17 58 60	
32	12	B	C 1 5 12 30 43 52 59 65 77	
33		29 79 82	11 47 49 62 70 71 74	
34	A	6 21 85	13 31 72	
35		8 10 11 19 39 63 68	7 33 40 50 69 73 86	51 66
36	37	14 35 36 38 42 56 58 73 76	D 15 36 48 57	A 1 32
37	16	C 27 31 47 74	10 34	
38	65	40 45 48 64	6 44 46 54 64 80	25 68
39	47	5 66 78	61 63 67	2 4 24 85
40		2 26 44 49 53 75 89		B 12 22 65 73 78
41	21 82	13 16 20 30 50 60 62	45 55	3 8 18 19 28 29 47
42	51	D 81 86 88	E	10 16 26 37 38 41 46 50 58 70 75 87
43	54 64	34		21 35 43 52 63 69 74 77 81 83
44	B 25 63	28	39	C 6 7 11 20 27 30 40 42 48 49 56 79 80 88
45	41	15		23 33 36 44 54 64 82
46	48 49 79	83		5 14 53 57 60 61 67 89
47	4 26 50 61 77	E 17 23 33 57 69 71		34 39 45 71 86
48	3 10 60	61		59
49	58	46 52 54 55 59 67		D 17 31 62
50	32 38 75			15
51	40 74			13
52	20 29 35 53 62			E 55
53	C 6 7 17 73			
54				76
55	8 45 78 85			
56	1 24 31 44 81			
57	23 30 59			
58	14			
59	5			
60	13 70			
61	39 56			
62	D 2 19			
63	27 52			
64	15 57			
65	11 34			
66	87			
67	55 80			
68	33 43 67 76 89			
69	28 83			
70	E 46 69			
72	42 71			
74	86			
76	88			

* See Table 1 for varieties represented by these numbers.
A, B, C, D, and E are infection categories, each comprising one-fifth of the yearly total range of infection.

or percentage of infection varies from year to year rather markedly. Climatic conditions are undoubtedly responsible for these differences. In Table 3 are shown rainfall and temperature data. It must be admitted that these weather data do not present a complete picture. Much more detail would be required to indicate important factors such as soil moisture and temperature at planting time, timeliness of rain storms, and relative evaporation losses. The influence of weather on root rot is discussed in a paper (4) published since the present article was prepared.

TABLE 3.—CLIMATIC DATA AT EDMONTON DURING MAY, JUNE, AND JULY FOR YEARS 1937 TO 1942, INCLUSIVE

Year	Average Temperature, °F.							Rainfall		
	Soil				Air			May	June	July
	Seeding	May	June	July	May	June	July			
	°F.	°F.	°F.	°F.	°F.	°F.	°F.	in.	in.	in.
1937	47	46	58	60	54	60	63	1.7	0.9	8.3
1938	51	52	63	71	51	61	64	1.4	4.7	3.2
1939	50	51	55	64	53	53	63	5.4	1.8	1.5
1940	42	53	56	58	55	57	61	2.6	2.5	3.7
1941	57	54	62	69	51	61	68	0.9	4.9	1.1
1942	36	39	53	67	51	56	63	1.5	8.5	3.4

The classification of the varieties according to their susceptibility to root rot in each year falls more or less smoothly into normal distribution curves, indicating the existence of what seem actual differences in resistance. The grouping into categories based on the range of infection-percentages is shown by the letters A, B, C, D, and E, dividing the range as nearly as possible into 5 equal parts. In any particular season these 5 divisions may be regarded as placing the varieties in a range of their relative susceptibility to root rot. Theoretically, it might be assumed that each variety would fall into the same category each year. Although this was not the case with all varieties, yet, in carefully reviewing the placements for the four seasons, it was found that some varieties consistently occurred in the lighter infection groups. Twenty-five of the varieties consistently grouped in the light infection classes were selected for further tests. These were arranged in lots of 5, in descending order of resistance. In addition, another control lot of 5 was selected as showing neither marked resistance nor susceptibility. Incidentally, this group includes some of our most commonly grown varieties of spring wheat.

In 1942 the 30 varieties were planted in 12-foot rows 1 foot apart and replicated 6 times. Seeding was on May 5, and notes were taken on August 20 and 21, before any of them had matured. The estimated time before maturity varied from 4 to 10 days for the different varieties. The infection rating data appear in Table 4.

During the 1942 season conditions were favourable for growth, with an abundance of rainfall well distributed throughout the entire growing season. Owing to the fact that the disease rating was purposely made somewhat earlier than usual, it was fairly light, with a percentage range from 14 to 31. The effect on infection rating of taking these data earlier is discussed in section B. Other factors that tended to decrease infection rating were the inclusion of the more resistant varieties in this test, and the effect on the pathogens of the significantly low average temperature of the soil during May and June.

TABLE 4.—INFECTION RATING OF 30 VARIETIES OF WHEAT AS PRODUCED BY ROOT-ROTTING FUNGI UNDER NATURAL FIELD CONDITIONS IN 1942

Variety*	Infection	Variety*	Infection
	%		%
22 Red Fife	22.3	35 Pioneer	17.2
25 Kota	18.8	36 Swedish	24.7
32 O.A.C. 35	14.7	38 Major	17.0
51 White Russian	17.5	47 Producer	16.7
65 Blue Ribbon	16.0	68 McMurachy's	15.2
18 White Fife	17.3	16 Canus	22.8
21 Huron	23.5	58 Axminister	19.7
24 Kitchener	19.7	66 Ceres × (Hope × Florence)	23.0
79 Double Cross	19.5	74 Early Prolific	20.2
82 Caesium	14.7	77 White Head	22.8
1 Kubanka	17.7	10 Marquis	24.5
29 Preston	19.7	13 Reward	31.2
37 Tartan	15.7	15 Red Bobs	26.8
41 Red Indian × Common Emmer	14.3	34 Prospector	24.7
73 Red Russian	16.3	72 Calcutta	27.0

F value for varieties 5.13, 5% point 1.59, 1% point 1.92. Twice S.E. of difference 5.3.
* The varieties are numbered as in Tables 1 and 2.

B. Effect of Time of Securing Data upon Infection Rating

It is common observation that root-rot symptoms, especially on the crown of the wheat plant, become more marked as the plant approaches maturity. Also, in the mature plant the problem of securing an accurate estimate of the root-rot damage becomes very complicated, because, in the ripening-off process, the basal parts take on a colour not unlike that associated with infection. An attempt to demonstrate this point was made in 1941. Fifteen varieties, differing in their reaction to root rot, were selected for the purpose indicated. These were seeded in 4 replicates, on land alternately in wheat and fallow in 12-foot rows, 6 inches apart. Twenty plants were rated for infection at two periods, namely, July 26, when the

plants were in the soft dough stage, and August 20, which was the approximate date of maturation of all the varieties. The infection ratings are presented in Table 5, where each variety has the number used to designate it in Tables 1 and 2.

The infection ratings at the first reading were all quite light, the lowest being 5% and the highest 17%. At the second reading the lowest average rating was 17% and the highest 40%. This range is less than that of the same varieties grown on the continuous wheat plot, as shown in Table 2, for 1941. Planting wheat alternate seasons with fallowing is known to reduce root rot, hence the difference observed was to be expected.

TABLE 5.—INFECTION DATA INDICATING THE TENDENCY OF SYMPTOMS PRODUCED BY THE ROOT-ROTTING FUNGI TO INCREASE AS THE WHEAT PLANT NEARED MATURITY IN 1941

Variety*	Average infection rating		Relative order of Susceptibility	
	July 26	Aug. 20	July 26	Aug. 20
	%	%		
5 Pentad	8.2	25.0	3	5
12 Little Club	5.0	17.0	1	2
13 Reward	15.4	40.4	14	15
16 Canus	9.0	25.0	6	6
28 H-44-24	13.1	31.6	13	10
33 Alberta 3	17.0	37.6	15	14
36 Swedish	8.4	26.2	4	7
43 Aurora	10.4	32.0	9	11
44 Early Russian	8.5	27.2	5	8
46 Master	11.1	33.5	11	13
52 Yellow Fife × Omega Gehun	11.1	21.9	10	4
53 Marquis × Kanred	11.7	33.4	12	12
73 Red Russian	9.1	15.0	7	1
77 White Head	7.7	19.0	2	3
10 Marquis	9.5	31.4	8	9

* The varieties are numbered as in Tables 1 and 2.

The increase in infection percentages between the two dates of recording was marked in the case of all varieties. The relative position of each variety as regards infection at the two readings changed but little, as may be seen from the table. A number of the varieties were the same as those used in the 1942 test, cited in section A (Table 4), and their resistance is again indicated in this test.

In 1942 an additional planting was made to determine the effect of obtaining the infection rating at different dates. Four replicates of the 30 varieties used in the variety test were planted May 5 on land fallowed in 1941 and previously in wheat for three years. Notes were taken on the roots and crowns of 20 plants from each row on July 27, August 5, and August 17, the last date being 4 to 10 days before maturity. The data appear in Table 6.

TABLE 6.—INFECTION DATA INDICATING THE TENDENCY OF SYMPTOMS PRODUCED BY THE ROOT-ROTTING FUNGI TO INCREASE AS THE WHEAT PLANT NEARED MATURITY IN 1942

Variety*	Average infection rating		
	July 27	Aug. 5	Aug. 17
	%	%	%
22 Red Fife	9.3	15.3	16.3
25 Kota	13.3	17.0	20.0
32 O.A.C. 35	10.0	13.8	17.0
51 White Russian	7.5	15.0	18.8
65 Blue Ribbon	11.3	21.8	18.5
18 White Fife	9.8	16.5	17.8
21 Huron	15.3	12.8	19.0
24 Kitchener	11.8	19.3	19.5
79 Double Cross	13.5	17.5	20.8
82 Caesium	10.5	15.8	21.0
1 Kubanka	12.0	20.0	25.3
29 Preston	11.3	18.0	26.8
37 Tartan	8.3	14.0	18.3
41 Red Indian × Common Emmer	10.8	16.3	19.8
73 Red Russian	14.3	20.8	22.8
35 Pioneer	11.3	18.8	17.0
36 Swedish	13.8	17.3	25.0
38 Major	9.5	16.3	19.8
47 Producer	15.5	19.5	26.5
68 McMurachy's	15.0	15.3	16.3
16 Canus	12.5	15.3	20.3
58 Axminister	12.8	14.3	20.8
66 Ceres × (Hope × Florence)	9.3	18.3	21.0
74 Early Prolific	8.3	13.5	18.5
77 White Head	11.8	16.5	23.8
10 Marquis	13.3	17.0	24.9
13 Reward	11.0	16.8	25.0
15 Red Bobs	10.5	16.0	25.8
34 Prospector	12.5	14.5	25.0
72 Calcutta	14.3	19.5	25.5

F value for totals of varieties 2.19; for age of plant 132.27; 5% point 1.55; 1% point 1.85
3.03 4.68

Twice standard error of difference 6.4.

* The varieties are numbered as in Tables 1 and 2.

It is apparent that the symptoms of root rot increased progressively during the month prior to maturity. Therefore, since wheat varieties differ materially in their spans of life, it is obviously necessary to secure infection data on them at the same relative stage of ripening. This would eliminate a certain degree of error encountered in taking notes on all varieties at the same time.

DISCUSSION

The data presented in this study indicate that, in spite of the disturbing influence of seasonal climatic factors on the range of infection from one year to another on the wheat varieties tested, certain ones seem to possess more inherent resistance to the root-rot complex than others (Tables 2 and 3). Some of those appearing to have appreciable resistance are, Red Fife, Kota, O.A.C. 35, White Russian, Blue Ribbon, Huron, Kitchener, Double Cross, Caesium, Kubanka, Red Russian, Swedish, Major, McMurachy's Selection, and White Head (Table 4).

Forster and Croll (2), concluded from the results of an exploratory study on 4 wheat varieties, that natural resistance is more important than the environmental factors, or the ripening behaviour, in influencing the development of lesions on the roots. We agree with this, but wish to emphasize the role of factors other than the inherent resistance of the plant in studies of this nature. For example, drought has been found to markedly influence the final infection rating. Early drought, by destroying portions of the root system, opens avenues not only for the entrance of soil-borne pathogens, but saprophytes as well. Also, drought, towards the ripening stage, causes a discolouration of the crown tissue difficult to distinguish from that associated with infection by the root-rotting fungi. It would appear from these studies that, in general, the inherent resistance of a variety can be more accurately identified from 4 to 7 days just prior to maturation than during the seedling stage or the period intervening. The reason for this is that under field conditions, in naturally infested soil, the maximum development of symptoms occurs just before maturity, although there is a gradual marked increase during the month preceding (Table 5). However, owing to the effect of variable climatic factors, it is not possible to make a general interpretation of this increase on a percentage basis. For example, in 1941 the amount of infection tripled in many cases in a little less than a month, and in 1942 the amounts doubled during a period of 22 days. Even an interval of a week can effect a considerable increase in intensity of symptoms.

Moreover, it is important that the varieties be grouped according to their dates of ripening. That is to say, the various groups that mature at different periods would be planted at the same time so that all varieties would be subject to like conditions during most of the growth period, and each group would be harvested at intervals of three or four days, corresponding to their dates of ripening. The data should be secured by one observer at any one station, as multiple observers necessarily introduce errors of personal judgment in estimating the infection symptoms on a numerical basis. Obviously, this factor would not be important when comparing data from different stations.

With regard to the relative merits of conducting resistance studies in the field versus the greenhouse in naturally infested field soil, the following observations, based on information obtained from these investigations may be outlined. In the greenhouse in pot culture it is fairly easy to secure killing of all seedlings by sufficiently increasing the inoculum, or, by decreasing it, to obtain a very light infection, either of which is not satisfactory. Also, under these artificial conditions the behaviour of the

pathogen tends to be far more erratic than in the field, where the soil microflora has become more stabilized. There is also the fact that seedling material which is obviously unsatisfactory for resistance studies, cannot be brought to natural maturity on account of space and other limitations.

Under field conditions, in naturally infested soil, not only does infection of the host tend to develop more gradually, and also later during the post-seedling stage, but the plants mature fairly normally, which is very desirable. But even here, if inoculum is applied as a spore suspension on the seed, or put into the drill in other forms, severe disease may develop and a high percentage of the seedlings be killed before or shortly after they emerge, and the remaining plants, having less competition, become abnormally vigorous and healthy. Consequently, the difference in numbers of surviving seedlings from an attack of this kind is of doubtful value in indicating the obviously limited natural resistance that a variety may possess. For the reasons mentioned it seems essential that the identification of varietal resistance should be attempted only in the field in naturally infested soil.

Unfortunately, no very outstanding degree of resistance has been discovered yet in this study, nor is such likely to be found, even when all other available varieties have been tested. However, the completion of this study would provide the plant breeder with necessary information for the development of new varieties with greater resistance to the root-rotting fungi.

SUMMARY

A progress report is submitted of the relative resistance during several years of 148 varieties and strains of spring-habit wheat to the root-rotting fungi, *Ophiobolus graminis*, *Fusarium* spp., and *Helminthosporium sativum*, under field conditions, and problems associated with testing for this resistance are discussed. The varieties and strains were found to fall rather consistently into different resistance groups. The studies show that it is very important that data on resistance be recorded from about 4 to 7 days prior to maturity, because, if delayed, the natural differences may easily become indistinguishable. Also, notes should be taken on varieties of different ripening habit at the same relative stage of maturation. The presence of dry soil conditions markedly complicates the interpretation of infection symptoms.

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LEVEL AND SOURCE OF PROTEIN IN POULTRY PRODUCTION

I. AS RELATED TO ECONOMICAL PRODUCTION OF GROWTH IN PULLETS[1]

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Maximum growth in pullets is not necessarily the most satisfactory growth. From a physiological standpoint the greatest body weight in a given time may not mean the production of the most sound individual. Under these conditions moreover, the feeds may not be used as efficiently for the production of gain in weight. In addition, rapid growth may be occasioned at a greater cost in consumption of feed containing high priced ingredients than the value of the increased weight of the bird would merit. Since the production of tissue other than bone in growth is largely a building up of protein materials, the level of protein in the ration becomes a consideration of major importance. Since feeds containing large proportions of protein are the most costly ingredients of the ration the factor of economy of production in growth is very pertinent to a study of the effect of proteins. Another factor related not only to economy, but also to hygiene in rearing, operations, is the supplementation of rations of varying levels of protein by adequate and suitable green range. The experiment herein reported was carried out as a wartime measure to determine to what extent the level of protein in rations could be safely lowered since it was believed that unnecessarily high levels of protein are commonly being fed. It was designed to furnish information on (1) the approximate level of protein which might be expected to give the most satisfactory and economical rate of growth commensurate with efficiency of utilization of feed and available pasture, (2) whether a large proportion of vegetable protein may be substituted for animal protein and at what level of protein feeding, (3) the simplification of feeding methods through the use of scratch grains as a diluent to the higher protein mash portion of the ration, and (4) the effect of the various levels and sources of proteins on subsequent egg production. The last mentioned will be considered in a later paper dealing with the egg production phase of the experiment.

The subject of protein levels and sources for both growth and egg production has been investigated and reported upon by many workers. This work has been reviewed recently by Heuser (1). As a consequence, references to individual work will be made only where pertinent to specific features of the work. It should be stated however, that workers are in general agreement as to maximum and minimum levels of protein, in the former case above which no further appreciable response may be expected and in the latter instance below which development is seriously retarded. Agreement is not so marked, however, with intermediate levels and with

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the balance between maximum growth, efficiency and economy. Supplementation under practical conditions by pasture, and simplicity of feeding methods have also usually not been considered in connection with protein levels.

EXPERIMENTAL

Six paddocks which had been in grass sod for some years were selected for the rearing phase of this experiment. Sexed, day-old Barred Rock pullets were randomized into 6 lots and reared in 10′ × 12′ movable colony houses, approximately 100 pullets to the group. The hatch was taken off May 15, making these chicks somewhat later hatched than usual for the area. The chicks were first allowed out on grass 18 days after hatching. Since each paddock measured 90′ × 80′ there were approximately 70 square feet per pullet equivalent to a rate of 600 birds to the acre. This rate represents approximately 25% heavier pasturing than is usually recommended. Actually a relatively dry summer was experienced and the green cover suffered accordingly, with the result that the experiment constituted a rather severe test of the ability of pullets to utilize low protein rations satisfactorily with only a limited opportunity for supplementation by consumption of fresh grass.

TABLE 1.—INGREDIENTS OF THE MASHES USED, WITH CHEMICAL ANALYSES

	Animal protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
	lb.	lb.	lb.	lb.	lb.	lb.
Wheat bran	15	15	15	15	15	15
Wheat shorts	15	15	15	15	15	15
Ground Oats	15	15	15	15	15	15
Corn starch	40	33	27	37	28	19
Meat meal (60%)	2	4	6	—	—	—
Fish meal (70%)	3	6	9	—	—	—
Skimmilk, dried	2	4	6	5	5	5
Soy bean meal	—	—	—	4	12	20
Dehydrated alfalfa leaf meal	6	6	6	6	6	6
Ground oyster shell	1	1	—	1	1	1
Bone meal	—	—	—	1	2	3
Salt	½	½	½	½	½	½
Cod liver oil (1850 A – 400 D)	½	½	½	½	½	½
Total	100	100	100	100	100	100
	%	%	%	%	%	%
Moisture	10.10	9.65	9.48	10.20	9.55	9.65
Protein	12.45	15.95	20.14	11.25	15.37	20.09
Fat (ether extract)	3.00	3.35	3.33	3.20	3.33	3.70
Ash	4.80	6.20	6.55	4.68	6.20	6.98
Crude fibre	4.97	6.19	5.58	5.16	6.80	6.82
N-free extract	64.68	58.66	54.92	65.51	58.75	52.76
Total	100.0	100.0	100.0	100.0	100.0	100.0
Calcium	1.025	1.239	1.194	0.935	1.234	1.557
Phosphorus	0.643	0.718	0.974	0.595	0.819	1.200

The paddocks were paired according to experimental treatment, one of each pair having the same level of supplemental proteins from animal and the other from vegetable sources. In the case of the latter, however, 5% of the supplemental protein of the mash mixture was from skim milk powder fed largely as a source of B vitamins but also with the object of supplementing the amino acid deficiencies of the vegetable protein source. Since it was desired to use mashes as low as 12% in protein, a level approximately that of common grains, while at the same time having appreciable quantities of animal or vegetable protein supplements in the mashes, it was necessary to use a feed source free of protein. Consequently corn starch was used as a diluent for this purpose.

The chemical analyses of the mashes fed are shown in Table 1.

It will be noted that in the above rations the basal portion of the mash made up a constant proportion of the ingredients in all instances, the variables being the animal or vegetable protein feeds and the corn starch. Also from level to level the proportion of the different animal feeds was constant even though their gross amounts varied in keeping with the required protein level. It was necessary to vary ground oyster shell and bone meal in order to maintain similar and adequate levels and ratios of calcium and phosphorus. With the exception of the low protein group, close agreement exists between levels of protein for the vegetable and animal protein mashes. The level of riboflavin was adequate in all mashes.

It should be noted that after the birds were out on green range in the sunshine the cod liver oil and dehydrated alfalfa leaf meal were omitted from the mash since they were no longer required and added substantially to the cost of the ration.

In keeping with one of the main objects of the experiment, the determination of economical levels of protein with maximum simplicity of adjustment of protein levels when required, the mashes set forth above were fed with scratch grain according to the following schedule:—

1 – 7 weeks inclusive—mash only
8 – 10 weeks inclusive—4 parts mash : 1 part grain
11 – 13 weeks inclusive—3 parts mash : 1 part grain
14 – 16 weeks inclusive—2 parts mash : 1 part grain
17 – 19 weeks inclusive—1 part mash : 1 part grain
20 – 22 weeks inclusive—1 part mash : 2 parts grain
23 – 24 weeks inclusive—1 part mash : 3 parts grain

The protein levels actually consumed considering both grain and mash of the above schedule and exclusive of the small and unmeasurable amount obtained from pasture are shown in Table 2.

The scratch grain used in this experiment was a commercial mixture containing wheat, cracked corn, oats, barley, buckwheat, sunflower seed and milo maize, which analysed 12.93% of protein. It will be noted from the above table that the level of protein actually consumed throughout the test was 12.66%, 14.69% and 17.13% for the animal protein groups and 12.00%, 14.34% and 17.02% for vegetable protein.

TABLE 2.—LEVEL OF PROTEIN ON BASIS OF ACTUAL CONSUMPTION

	Animal protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
1 – 7 weeks inclusive	12.45	15.95	20.14	11.25	15.37	20.10
8 – 10 weeks inclusive	12.55	15.35	18.70	11.60	14.88	18.67
11 – 13 weeks inclusive	12.57	15.19	18.34	11.67	14.76	18.31
14 – 16 weeks inclusive	12.61	14.94	17.74	11.81	14.56	17.71
17 – 19 weeks inclusive	12.69	14.44	16.53	12.09	14.15	16.52
20 – 22 weeks inclusive	12.77	13.94	15.33	12.37	13.74	15.32
23 – 24 weeks inclusive	12.81	13.68	14.73	12.51	13.54	14.72
Average*	12.66	14.69	17.13	12.00	14.34	17.02

* Weighted on the basis of actual consumption.

All birds were weighed individually weekly and the feed weighed back to obtain figures for feed consumption. The criteria used to determine the comparative efficiency of the different treatments were body weight, feed consumption, mortality, and cost of rearing.

Throughout this report the term vegetable protein is used to designate those groups whose supplementary protein was largely supplied by soy bean meal. On a basis of actual consumption the animal feed (dried skim milk) made up 2.8% of the total feed intake on the average for all vegetable protein rations, i.e. 1% of the protein intake was from an animal source. During the more critical period of the chicks growth, from 1 to 7 weeks, the figures were 5% and 1.75% respectively.

RESULTS

The growth data obtained during the whole rearing period are graphically presented in Figure 1, while all the pertinent information for 24 weeks of age is summarized in Table 3.

TABLE 3.—BODY WEIGHT AT 24 WEEKS AND CONSUMPTION OF FEED AND PROTEIN

Protein source and level	Mean level of protein	Body weight	Average feed consumption per bird	Average protein consumption per bird
	%	gm.	gm.	gm.
Low animal	12.66	1904	1385	175.4
Medium animal	14.69	2073	1404	206.3
High animal	17.13	2193	1556	266.5
Low vegetable	12.00	1751	1383	165.3
Medium vegetable	14.34	2067	1831	262.1
High vegetable	17.02	2145	1681	286.1

Body Weight as a Function of Age

In Figure 1, actual mean body weight in grams is plotted against age in weeks. An opportunity is thus given to compare rate of growth during the whole growing period to 24 weeks of age at which time the most mature birds of the high and medium animal protein groups were laying their first eggs. It is immediately obvious that the level of protein for the low protein groups was insufficient, since almost from the start of the experiment their body weights were very much and significantly lower than those of all other groups. This discrepancy, rather than decreasing with age as might be expected on the basis of a presumed lower requirement of

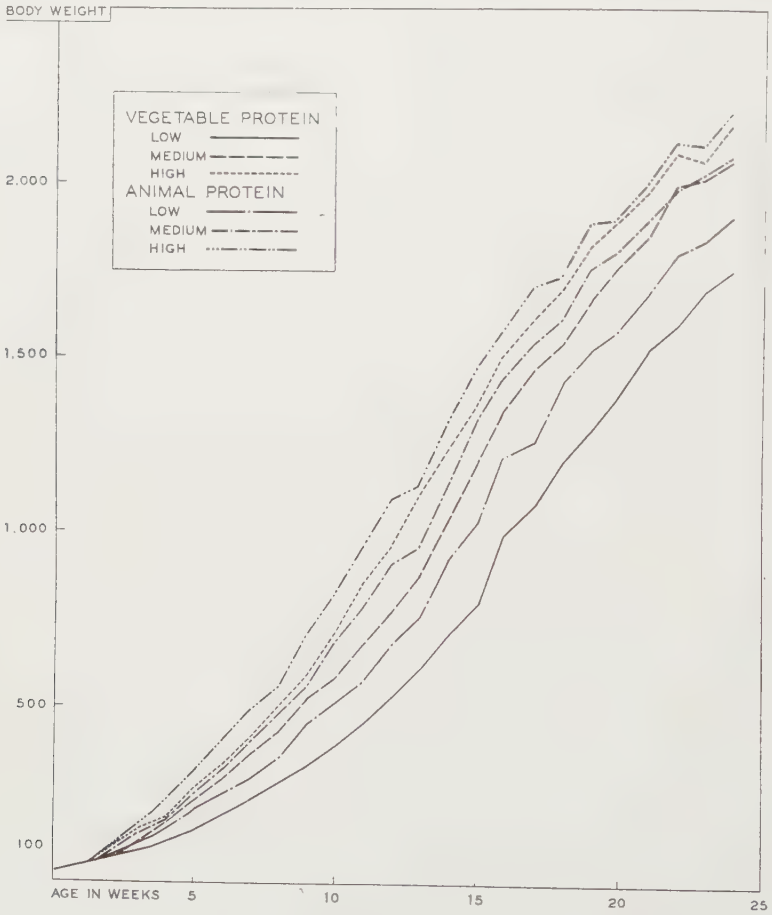

FIGURE 1

protein with advancing age and reduced rate of growth, actually increases. At 40 weeks of age the low vegetable and animal protein groups were of equal weight and some 160 grams lighter than the other groups indicating that the depressed growth of the rearing period was evident through the period of egg production. The high protein groups also grew at a significantly more rapid rate during the greater part of the rearing period than

the medium protein groups although the differences were relatively small in a practical sense, the greatest difference at 24 weeks being 120 grams per bird. Differences between animal and vegetable protein were significant at the low protein level only, which might argue a more marked deficiency in the vegetable protein when fed at a borderline level or might be due to a slightly higher level of protein in the low animal protein ration or to a combination of both factors. It was noted at the conclusion of the rearing phase of the test that the medium animal protein group, though 120 grams lighter in weight than the high animal protein group, was as well developed sexually as indicated by general observation of the groups for comb development and by the fact that slightly more birds were in production at 24 weeks of age. The vegetable protein groups were definitely less mature sexually at this age.

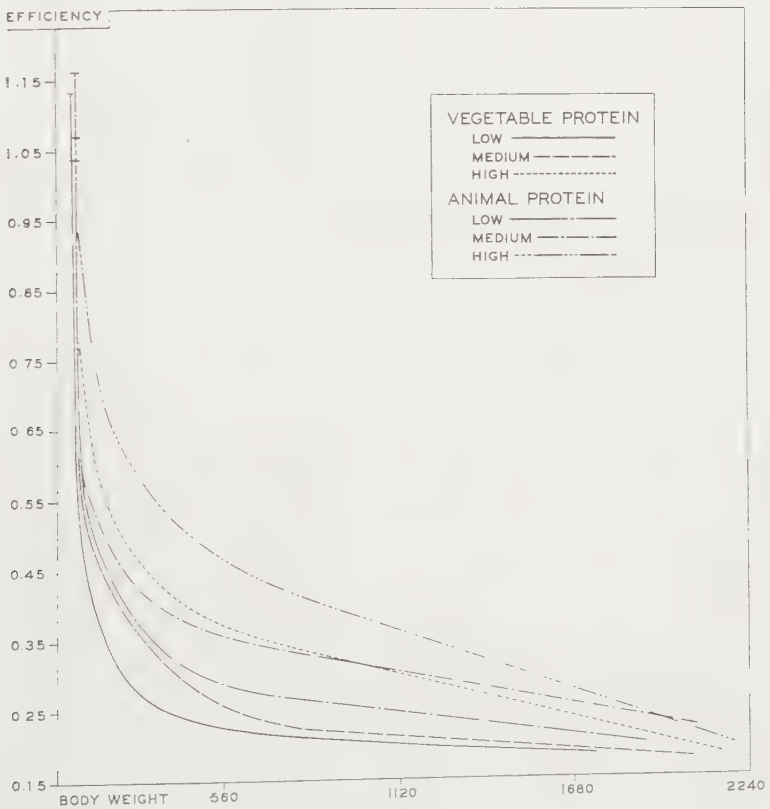

FIGURE 2.

Efficiency of Use of Feed and Protein

The amount of feed or protein required to bring a pullet to any given weight is an important factor in that it indicates the efficiency of use of feed or protein for the maintenance of body weight and the production of gain. Efficiency is usually expressed as a ratio between gain and feed consumed, indicating the gain produced per unit of feed consumed or vice

versa. Since the feed used for gain and for maintenance of the body cannot be separated it is preferred to express efficiency as body weight ÷ the feed consumed to attain that body weight, including that for both gain and maintenance. If efficiency, thus calculated, is plotted against age a fallacious interpretation may result in that the most efficient group at any age may be much smaller in actual weight than other groups, a fact which is not shown in the curves thus plotted; at the same body weight, which would require a longer period of growth for the lighter group, the efficiency would probably be very markedly reversed. For this reason both feed and protein efficiency were plotted against body weight. Since the protein levels were changed periodically according to a set plan, as previously indicated, the live weight to feed relationship does not conform

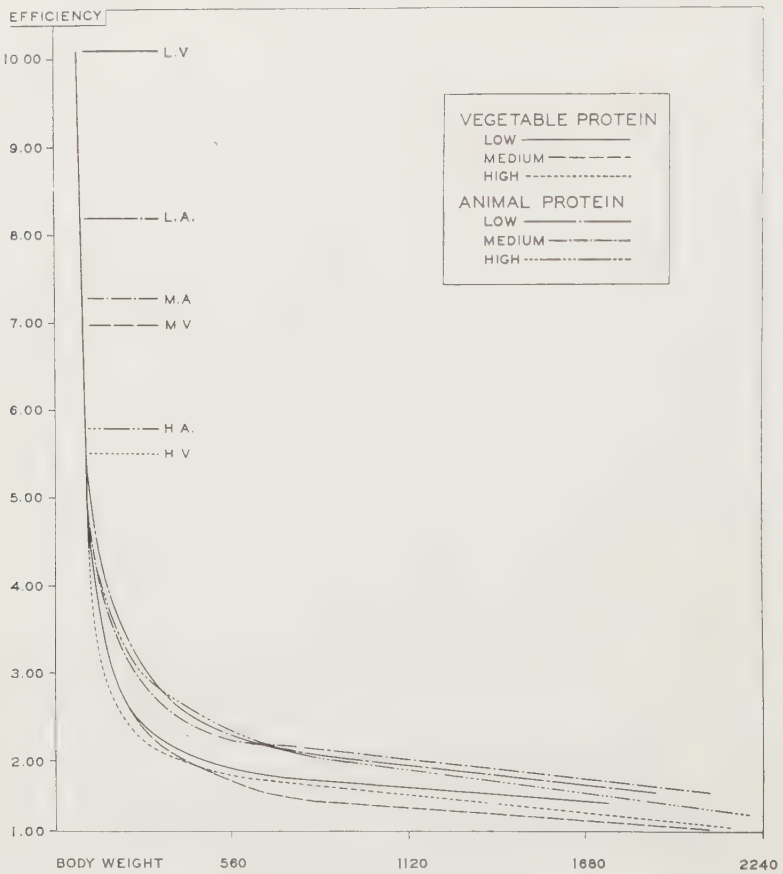

FIGURE 3

to the curve of the law of diminishing increment, consequently the Spillman equation and the equation for a straight line derived therefrom as used by Titus (3) and Hammond *et al.* (2) are not strictly applicable to these data. Figure 2 shows efficiency as derived from the ratio between body weight and cumulative feed plotted against body weight. Figure 3 shows similar information for protein.

A consideration of Figure 2 shows that the group fed high animal protein was more efficient in the use of feed than any other group, followed by those on medium animal protein and high vegetable protein which do not differ significantly. Low animal protein and medium and low vegetable protein were relatively inefficient.

Since one group could be more efficient in its use of feed but less efficient in its use of protein because of a higher level of protein in its feed, the protein efficiency in relation to body weight must also be considered. Figure 3 indicates that protein efficiency actually did not parallel efficiency of feed. The greatest efficiency, particularly at the higher body weights, was attained by the medium and low animal protein groups followed by the high animal protein group. The vegetable proteins were definitely less efficient in this respect than the animal proteins.

Mortality

Mortality of pullets exclusive of what may be termed incubator mortality, that is, deaths during the first 2 or 3 days, before the feeding treatment could possibly have any effect, and of several accidental deaths was as follows:

	Animal Protein			Vegetable protein		
	Low	Medium	High	Low	Medium	High
Original number	100.00	98	97	95	93	92
Deaths (to 24 wks.)	14	2	6	15	27	14
Percentage mortality	14.00	2.04	6.19	15.79	29.03	15.22

As far as could be ascertained by autopsy and by observation, no conditions of an epidemic nature were encountered and most of the mortality was from birds which developed poorly and subsequently died or were killed because of a hopeless condition. The medium vegetable protein must be excepted from the above statement since a very high mortality was experienced during the second week from an unexplained cause, considered to be probably due to a management factor. If these deaths are excepted, a mortality of 14.29% was experienced by this lot which is in line with that of the other vegetable protein groups. The effect of this environmental disturbance was reflected also in the efficiency of the group due to abnormally high feed consumption as can be noted from Figure in and for this reason little weight is placed on the data from this group 3, relation to comparable levels and sources. It may be safely assumed, although comparisons of mortality are difficult, that the mortality was significantly lower on the medium and high animal protein levels than on the low level. It would also seem reasonable to assume on the basis of these data that a higher mortality may be expected with protein from a vegetable rather than an animal source.

Relative Economy of Different Levels and Sources of Protein

In the final analysis the cost of rearing of the mature pullet is a most important consideration. This has been calculated, covering feed costs only, on the basis of current feed prices and is shown to 24 weeks and per pound of bird at 24 weeks of age (Table 4).

TABLE 4.—FEED COSTS IN REARING TO 24 WEEKS OF AGE

	Per bird	Per pound
	cts.	cts.
Animal proteins		
Low	33.11	7.89
Medium	36.32	7.95
High	41.88	8.65
Vegetable proteins		
Low	34.56	8.95
Medium	47.11	10.34
High	44.28	9.36

Protein supplements—meat meal (60% prot.) $3.25 cwt.;
fish meal (70% prot.) $3.60 cwt.;
soy bean meal $2.35 cwt.;
skim milk powder $7.75 cwt.

Feed costs to 24 weeks are decidedly in favour of the lower protein levels. Since the weights at 24 weeks varied greatly a more critical test of economy is the comparison per pound of live weight produced. In spite of the smaller cost of the lower protein rations the greater increase in weight at the higher levels made the cost per pound very similar. Actually the cost per pound of pullet on the low animal protein ration is 99% of that on the medium protein whereas the cost of the latter is 92% of that of the high protein ration. That is to say nothing is to be gained in economy by using the low protein ration, whereas a saving of 8% could be made by using the medium protein ration rather than the high protein one. Considering vegetable proteins the low protein ration had a cost of 96% of the high protein ration, a relatively small difference. The cost of the medium vegetable ration is entirely out of line with expectation due to factors previously stated under the heading of mortality. It should be noted that where mortality is reduced to terms of economic loss the low protein level and the vegetable source suffer still further by comparison.

DISCUSSION

On the basis of weight attained at any given age these data indicate the low protein levels to be inadequate. A considerably lower body weight at 24 weeks combined with a much longer rearing period as indicated by degree of sexual maturity at that time seriously interferes with the opportunity for economical production of eggs. This is particularly true when considered in the light of the very great effect of days to first egg on annual production of eggs. Between high and medium levels of proteins on the

other hand, body weight differences, although significant, were of small practical value. Differences between the animal and vegetable protein groups were consistent but relatively unimportant.

Efficiency, as indicated by the body weight produced per unit of feed was definitely superior for the high animal protein group followed by the medium animal and high vegetable groups which were approximately equal. Efficiency of the remaining groups was relatively low. On the basis of actual protein intake, however, the medium animal protein group was outstanding, followed by high and low animal protein groups. The vegetable protein groups were relatively low in protein efficiency.

For actual and efficient production of body weight, therefore, the high and medium levels of animal protein are outstanding with only the high vegetable protein in a similar range of quality.

FIGURE 4. Severity of pasturing—paddocks of low, medium and high animal protein groups left front to back and low to high vegetable groups right front to back—dark patches, reseeding with alfalfa.

Mortality definitely favoured the medium and high animal protein groups. All the vegetable and the low protein animal groups were quite high in mortality. The economic importance of this factor is very great since with each death the original cost of the chick plus the feed to raise it to time of death is complete loss.

Feed cost per pound of pullet raised to 24 weeks of age differs by approximately 1% between medium and low levels but by 8% between medium and high thus making an appreciable balance in favour of medium animal protein. In spite of the lower cost of vegetable protein rations their cost per pound of bird produced was greater than that of the animal protein groups.

On the very low levels of protein used in this experiment, any supplementation to the ration which the birds were able to make through use of the available pasture was not sufficient to bring their ration to the level of the higher protein rations in efficiency. Where medium levels of protein were fed, however, the level of protein given plus the herbage consumed produced almost as rapid growth and a similar or even slightly superior efficiency of use of protein. That this supplementation was a factor is shown in a very interesting contrast of the state of the pasture in midsummer as shown in Figure 4.

It is quite apparent that the high animal protein ration required little if any supplementation and it was observed that these pullets did not pasture the grass to any extent. The medium animal protein group pastured their paddock intensively, and the low protein more so. It was also observed that all moulted feathers were picked up and consumed in the low animal and vegetable protein groups but not in the others. The paddocks of the vegetable protein groups appear to be more intensively pastured than those of the animal protein group. A decided contrast between the same levels of animal and vegetable protein is evident in the top two paddocks (high levels of protein). It seems obvious that even the high vegetable protein ration was inadequate. In this connection it should be reiterated that the rations of all groups were balanced with respect to all known factors other than protein.

Since in this experiment medium animal protein gave practically equal growth and greater protein efficiency than high animal protein these birds apparently were able to make up their deficiency, if any existed, through utilization of their pasture. A greater area for pasturing and/or a season of greater rainfall without doubt would have made this supplementation complete.

SUMMARY

Six groups of approximately 100 pullets each were raised under closely identical conditions and fed rations comparable in all known respects excepting level or source of protein. The following observations are made as a result of this study.

1. Pullets which received 17% protein from either a vegetable or animal source during 24 weeks of growth attained significantly greater body weights on the average at that age than did pullets on rations containing 14.5% or 12.5% of protein. The differences between the higher levels were small, the greatest being 5.5%. Each of the higher levels proved considerably more satisfactory than the 12.5% levels. At all levels, animal protein was significantly more efficient on the average than vegetable protein, but, with the exception of the lowest level, these differences were small.

2. On the basis of efficiency of utilization of the ingested protein per unit of body weight produced, the 14.5% animal protein ration was slightly superior to the 12.5% and to the 17% to an even greater degree. The vegetable protein rations were decidedly inferior to the animal protein in efficiency.

3. Mortality was definitely lower on the medium and high animal protein levels than on the low animal protein ration. It was also consistently higher on all levels of vegetable protein.

4. Cost per unit of body weight produced varied little between the 12.5% and 14.5% animal protein levels but was approximately 8% less for the 14.5% than for the 17% level of protein. In spite of lower cost of the vegetable protein supplement these groups were slightly less economical than those on animal protein. The higher mortality of the vegetable protein groups, if reduced to a cost basis, widens the gap between animal and vegetable protein rations still further if considered on a basis of economy of production of growth.

Evidence is presented to show that the pasture was utilized to an increasing degree on the lower levels of protein. The high animal protein ration (17%) would appear to have been adequate in most respects since the pasture of the group on this ration was only very lightly grazed. There is a suggestion that the vegetable protein groups felt the need of supplementing their ration to a greater degree than the animal protein fed groups through an increased intake of pasture grass.

In consideration of the results obtained as judged by all the above criteria, it is concluded that feeding a 15.5% protein mash to seven weeks followed by a systematic reduction of protein by dilution with scratch grain so that a ratio of 3 parts of grain to 1 of mash (13.7% protein) was reached at 24 weeks (average protein ingestion of 14.5%) may be expected to give as satisfactory results as the usual practice of 20% to 14.75% with a 17% average when pasture is available as was the case in this experiment. Since the paddocks used in this test were over-pastured and the growing season particularly dry, the above conclusion would hold under most conditions.

It is also concluded that a protein level of 12.5% using increasing ratios of scratch grain as above is too low for satisfactory results.

Vegetable protein when making 99% of the total protein of the ration on the average cannot be expected to give as good results as animal protein under conditions similar to those pertaining during this experiment. Results obtained were reasonably satisfactory, however, and in time of scarcity of suitable animal feeds or where price differentials are more in favour of the vegetable protein supplements than was the case in this instance, they would fill a very useful place in the poultry feeding regime even up to almost complete substitution for animal protein feeds.

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THE RICHARDSON GROUND SQUIRREL, *CITELLUS RICHARDSONII* SABINE, IN SOUTHERN ALBERTA: ITS IMPORTANCE AND CONTROL

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The greater part of the material in the following article was gathered during the course of the Alberta Rocky Mountain Spotted Fever and Sylvatic Plague Survey. This survey was organized in 1938 and has been in the field every summer since that time. As the survey deals particularly with the Richardson ground squirrel, it was necessary that much information regarding its life history, habits, etc. be gathered so that an appreciation of its role in disease transmission could be had.

HISTORICAL

Ever since the first settlers moved into southern Alberta and began to cultivate the land, the Richardson ground squirrel (or as it is mistakenly called—the Prairie Gopher) has been recognized as a serious agricultural pest from its habit of invading grain fields and vegetable gardens where it feeds on and destroys the tender shoots and seedlings. Large fields of grain and entire garden patches have been completely destroyed by this rodent.

As more settlers arrived and more land came under cultivation so did the ravages of this pest increase, until at last an organized effort for control was demanded by the farmers. This demand was heeded, and the Provincial Government by statute empowered Local Improvement Districts in 1907, and councils of Rural Municipalities in 1911, to make provision for combatting the ground squirrel nuisance through the expenditure of public monies (17).

Two methods of control were adopted:

1. The distribution of free "gopher poison".
2. The payment of a cash bounty for each animal destroyed.

The first method was a more or less haphazard affair. The poison was issued by the Municipal Secretary to those farmers who called for it at his office; but at no time was a definite control campaign organized over a large area. The results of such a haphazard method would be obvious. Those progressive farmers who had an interest in farming and were trying to become established carried out an intensive control campaign on their own land, while less-interested farmers did not attempt any control. But these less-interested farmers were not the only offenders—lands owned by Dominion and Provincial governments, the Hudson's Bay Company, and

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the railway companies were also left unpoisoned. Such lands were ideal places for the multiplication of these pests and as a consequence the number of ground squirrels increased rather than decreased.

The second method was the better of the two because the payment of a cash bounty for the destruction of ground squirrels had a great appeal to school children, especially small boys. With the bounty as an inducement the school children snared, trapped, shot and poisoned ground squirrels and removed the tails which had to be handed in as proof that the animals were destroyed.

With the establishing of fur farming in this province ground squirrels became of some economic importance. Mink and fox farmers, especially, began using ground squirrels as a food for their animals, and in certain areas these farmers paid cash for each animal delivered to their farms. The only stipulation they imposed was that the animal must have been shot or trapped. Once again small boys entered the picture and in fur farming areas the ground squirrel population rapidly decreased.

In 1937 a mink farmer at Stanmore died from some disease highly suggestive of bubonic plague, and the circumstances surrounding his death suggested that he might have contracted the infection from ground squirrels in his district.

In 1938 an investigation into the circumstances surrounding his death was undertaken, and in 1939 it was definitely determined that the ground squirrels in his area were carrying bubonic (sylvatic) plague infection; it was further determined that he, in all probability, died from bubonic plague contracted from infected ground squirrels (4, 13, 14).

In 1940 the bounty on ground squirrels was removed and warnings against the handling of these animals were issued. At the same time an appeal was made for farmers and others to carry on more intensive poison campaigns for by so doing they would not only protect their crops but also their health (5).

THE ANIMAL

The Richardson ground squirrel, *Citellus richardsonii* Sabine (2), is often mistakenly called the prairie gopher; it also goes by the common names of yellow gopher, flicker tail and picket pin gopher (17). These names are not correct, for this animal is a Spermophile and should always be referred to as a ground squirrel.

Description

This animal (Figure 1) when full grown is about 12 inches long and varies in colour from tawny to a near-white. There is a great variation in size and colour in different areas and this variation is likely due to the soil type and kind of food.

The ground squirrels in the extreme southern part of the province are usually 10 to 12 inches long and brownish-grey in colour, while those north of a line drawn east from Calgary are predominantly larger and a greyish-white in colour. There is a very definite intermingling of size and colour

in this species throughout the whole of southern Alberta; in fact, so much so that one is led to believe that there are numerous sub-species of this animal inhabiting the same range.

Life History

The life history of this rodent is fairly simple. The hibernating animals appear in early spring, March or April, depending upon the kind of weather prevailing, and as soon as they emerge mating takes place. The period of gestation is about 27 days, and the young are born covered with fur. Within a few days after birth the young can fend for themselves. Six to eight are born to a litter and there is only one litter per year. Young ground squirrels become noticeable in Alberta during May.

FIGURE 1. Richardson Ground Squirrel.

When a month or two old the young ground squirrels establish their own burrows, usually near the parent, and carry on their own life. The colony tendency, although present, is not as highly developed as that which pertains in the Columbia ground squirrel, yet it is sufficient to keep the animals grouped close together. This gregarious habit has a definite protective value for at the first sign of danger the ground squirrels dive into the nearest burrow. It is doubtful if there is a great deal of "visiting" in neighbouring burrows, for it has been observed that the occupant resents the invasion of its burrow by its neighbours except in times of danger.

During the late summer preparations are made for hibernating, and each animal busies itself in collecting grass for its nest, and a store of seeds, roots and bulbs for food. The material gathered during these foraging trips is carried to the nest in the cheek-pouches. At the first sign of cold weather, usually around September 15, the majority of the animals are in hibernation. This will, of course, vary with the kind of fall weather prevailing and on October 12, 1942, a very warm, sunny day, many Richardson ground squirrels were still active.

Habits

The Richardson ground squirrel is a prairie-inhabiting rodent and lives in the ground. The burrows, which are used as shelter, vary in depth and length depending upon the soil type and time of year. The winter burrows are usually very deep and approach 20 feet in length, while the summer burrows are shallow and 8 to 10 feet long. Each summer burrow has an average of 8 openings scattered over an area 10 to 15 feet in diameter; the winter burrow contains a grass-lined nest and a store of food, and has only one opening which is plugged from the inside by the ground squirrel when it goes into hibernation.

The usual burrow entrance consists of an opening on one side of the mound that contains the soil removed from the burrow. This mound serves both as a protection for the burrow entrance and as an observation post for the animal. There is, however, another type of entrance that is frequently noticed in the spring and summer. It is a small, round hole in the ground and is devoid of any mound. This burrow is made by the young ground squirrel and leads from the nest to the ground surface, and as it is dug from the inside of the nest, all of the soil is pushed back into the winter burrow and is likely removed by the mother ground squirrel.

It is held by some that ground squirrels hibernate close to the ground surface, and as proof of this there are records of hibernating ground squirrels being turned up during early spring ploughing. This appears reasonable for it is obvious that this animal would hibernate above the burrow level in order to escape the flooding that would occur from rain and melting snow seeping into the burrow.

Ground-squirrels are mainly vegetarians feeding on seeds and roots, with wild onion being one of their favorite foods. They are also particularly fond of such insects as crickets, grasshoppers, caterpillars and cutworms. The authors have observed them digging cutworms from the soil and eating them. Carnivorous tendencies, although latent, appear to be well developed and these rodents are often observed feeding on the carcasses of other ground squirrels, especially on highways where the animals have been run over by automobiles. In such cases the killed animals are usually flattened out with the entrails showing. The fact that the blood and entrails are exposed may act as an attractant and be responsible for the carnivorous habit, for this action has never been observed in fields and on prairie land.

Ground squirrels have definite periods of time which they spend in the open. These periods are usually devoted to feeding, and to the collecting of material to carry them through the winter. The first period of daily activity starts about daylight and lasts for approximately two hours. The next period continues from about 10.00 a.m. to 2.00 p.m.; and the final period extends from about 4.00 to 8.00 p.m. At these times the animals can be seen sitting up like "picket pins", or dashing back and forth in their search for food. At all other times of day those ground squirrels that venture forth are very wild and scurry madly from burrow to burrow (3).

Weather conditions have considerable effect on their activity. During high winds the animals do not venture far from their burrows and are on the alert for any possible danger. During rains they will venture forth in the late afternoon to feed, and at this time they appear very sluggish.

In common with other types of wild animals the ground squirrels have no mercy on their deformed or crippled members. Such members are attacked and killed or driven out of the area. Sickly animals are also destroyed and often their burrows are taken over by their destroyers.

Range

The range of the Richardson ground squirrel covers practically all of the Great Plain area in Canada, and in Alberta (Figure 2) it is native to all of that region bounded as follows:— on the east by the Saskatchewan border; on the south by the Montana border; on the west by the C.P.R. from Pincher Creek to Lacombe; and on the north by the Battle River (3, 4, 6, 7, 8, 17).

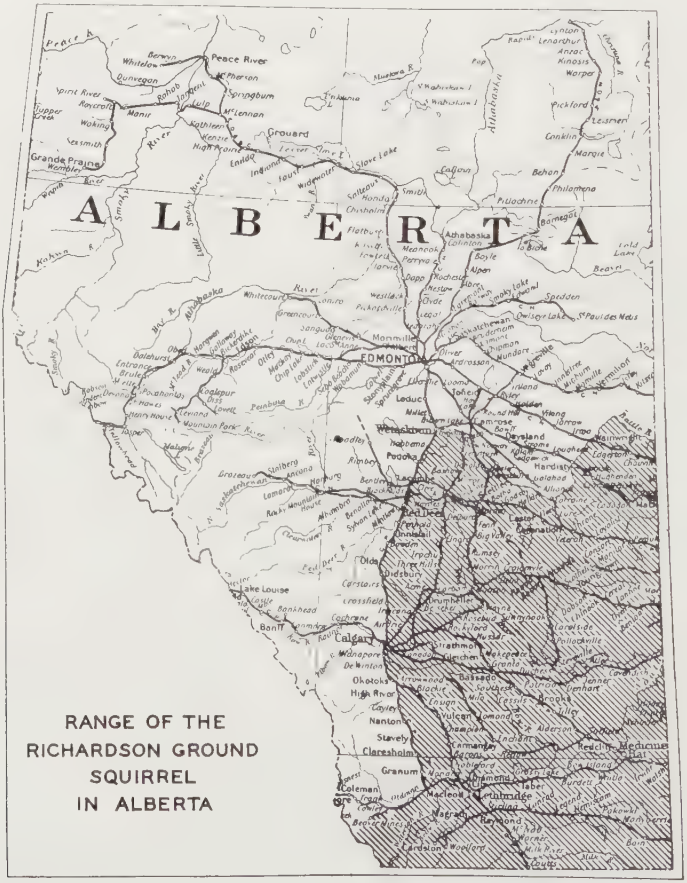

FIGURE 2. Range of the Richardson Ground Squirrel in Alberta.

Along the foothills this animal has invaded the range of the Columbia, or Mountain ground squirrel, and specimens have been taken at Cowley, and in the Red Rock Canyon at Waterton. There is a very interesting situation along the foothills where these two species meet, for a very definite intermingling of burrows occur. There is no known records of these animals cross-breeding, but the fact that the animals occupy the same limited range suggests that they are tolerant of each other (3).

Enemies

The ground squirrel has a long list of natural enemies. Of these, in order of importance, are: hawks, owls, weasels, badgers, coyotes, snakes, dogs and domestic cats.

Hawks are the greatest single factor in the natural control of ground squirrels, and every effort should be made to encourage their increase by declaring them a protected bird. As the law stands at present these birds may be shot at any time.

Owls play a very important part in control, especially burrowing owls, for they catch and eat large numbers of ground squirrels. However, the burrowing owl occupies a unique position because its value as a control agent may be offset by its ability to carry and transmit infected ground squirrel fleas (8).

Weasels, which are vicious blood thirsty killers, account for large numbers of ground squirrels each year. Their method of attack is direct and they will plunge headlong into a burrow after their victim. They usually seize their prey by the back of the neck and with one snap of their razor-like teeth they sever the spinal column. The ground squirrels have a great fear of weasels and when one invades their territory they all flee, squeaking with terror, for their burrows.

Badgers and coyotes, because of their scarcity have not, in late years, been a very important means of control.

The importance of snakes is not well understood and much confusion exists in regard to the part that they play in control. It is often stated that when rattlesnakes invade an area the ground squirrels immediately disappear, and it is commonly supposed that the snakes kill the animals. This theory does not hold up under observation for ground squirrels have been found in large numbers in areas thickly infested with rattlesnakes.

In one area of prairie land north of Medicine Hat ground squirrels have practically disappeared and although rattlesnakes are present it is obvious that they are not responsible for the disappearance (3, 8).

Dogs and domestic cats exercise only a slight control on ground squirrel numbers, and this only in thickly settled regions.

Ectoparasites

Ground squirrels, in common with all animal life, suffer from ectoparasites. These are usually lice, fleas and ticks, although there are other insects that sometimes attack these animals.

The lice are not of much importance, and as they have never been studied in detail their species are not well known.

The fleas, because of the fact that they can, and do, transmit a serious rodent infection from ground squirrel to ground squirrel, and from ground squirrel to man, are of great importance and considerable attention has been paid to them (5, 7, 12, 13, 14, 19, 20).

The following list records the fleas known to infest the Richardson ground squirrel in Alberta (7):

Name	*Locality taken*
Opiscrostis labis J. & R.*	Stanmore
Opisocrostis tuberculatus B.	Stanmore
Oropsylla rupestris Jord.*	Stanmore, Lethbridge
Hystrichopsylla dippiei Roth.	Stanmore
Epitedia spp.	Stanmore
Tamiophila spp.	Stanmore

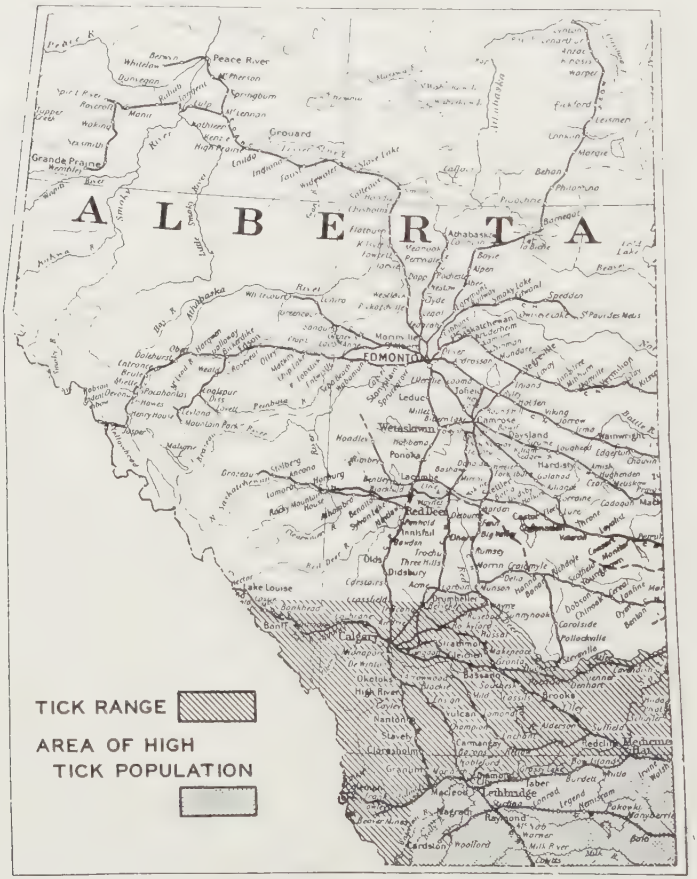

FIGURE 3. Tick Range in Alberta.

The Richardson ground squirrel is the main host for a tick that is of great importance to public health in this province (1, 3, 4, 6, 8, 10, 22). This tick, *Dermacentor andersoni* Stiles, is commonly called the "sage tick", "wood tick", "sheep tick" and "spotted fever tick". It actually is the Rocky Mountain spotted fever tick and should be known as such. The range of this tick extends from the Saskatchewan boundary to the British Columbia boundary, and from the Montana boundary to the Red Deer

* Known transmitters of sylvatic plague.

River. The area of highest population is located in southern Alberta, south of the Canadian Pacific Railway from Walsh to Macleod (Figure 3). It is this area, too, that contains the highest percentage of Rocky Mountain spotted fever and Tularaemia infected ticks (8).

Many other species of tick also infest the Richardson ground squirrel but so far only the one species has been identified.

Internal Parasites

No definite attempt has been made to collect and study the internal parasites of the Richardson ground squirrel, but observation carried on during the past 5 years show that in certain areas these animals are heavily infested with various parasites. The Hanna-Youngstown-Cessford, and the Brooks-Bassano areas contain a very high percentage of parasitized animals. These parasites infest either the alimentary tract or the liver or both.

The parasites collected consisted of tapeworms, roundworms and a small worm in the liver. Specimens sent to the Parasitologist at Parasite Institute, Macdonald College, Quebec, were identified as follows:

Filaria, new species
Capillaria hepatica—eggs in the liver.
Spirura sp. probably *infundibuliformis.*
Physaloptera sp.

"Scabby Gophers"

Ground squirrels are often seen that have large scabs on the back and sides. The cause of these scabs is not known but it is believed that they are healed wounds received during mating or in an attempt to mate. The Alberta survey has examined many "scabby" animals but the lesion does not extend below the skin. A widely held belief which may be true, states that this condition is due to mange.

Population

In order to arrive at a proper estimate of ground squirrel population it is necessary that each type of land, from virgin prairie to irrigated land, be evaluated separately and accurately as to its population (8).

Observations carried out over a 5-year period give a very accurate picture of population conditions and, paradoxically enough, those areas in which the ground squirrels *appear* to be the most numerous are the areas (with the exception of irrigated districts) in which the population is the lowest; and the reverse is also true. Such a statement is hard to believe, but when each type of land is examined separately the truth of the statement becomes apparent.

Prairie land, which is the natural habitat of ground squirrels, *appears* at first glance to harbor very few animals per acre. If, however, an acre is surveyed closely it will be found that the ground squirrels are scattered evenly over the whole area. Counts show that there are approximately 60 burrows per acre, and allowing 8 burrows per animal this gives a population of about 8 ground squirrels per acre. The point to remember is that there is an even distribution of animals over the whole acre.

Grassland which approaches prairie in regard to the fact that it is seldom, if ever, cultivated has the next highest population with approximately 6 ground squirrels per acre. Here again the dispersion over an acre is uniform and these animals are not apparent to the casual glance.

Abandoned land is land which was originally prairie, then broken and cultivated, and is now in the process of going back to native grasses. This type of land is usually badly infested with weeds and may contain numerous "blow-out" strips in which the soil lies bare. The *apparent* population on this type of land is very high for the animals are concentrated on the grassed-over land and appear very numerous. On examination, however, it is found that large areas are devoid of animals, and a count will show that the average population is about 5 ground squirrels per acre.

From the number of ground squirrels visible along the roads and on the headlands in intensively cultivated areas it would *appear* that the population was very high. If, however, such areas are examined in detail it soon becomes apparent that practically all of the ground squirrels are concentrated in such places, and that the cultivated land is entirely free of animals. In other words, there is a concentrating of ground squirrels along the margins of cultivated fields. This is a very hard fact to grasp at first but actual counts show that the average population is approximately 3 ground squirrels per acre.

Under irrigated conditions the ground squirrel population on all types of land is reduced to a minimum, for irrigation acts as a control agent through the flooding of burrows and the drowning of animals. On this type of land the average population is about 2 animals per acre.

Table 1 shows the approximate population per section for each type of land. (8).

TABLE 1.—INCIDENCE OF GROUND SQUIRRELS

Land	Animals per acre	Burrows per acre	Animals per section
Prairie	8	64	5,120
Abandoned	6	48	3,840
Grassland	5	40	3,200
Cultivated	3	24	1,920
Irrigated	2	16	1,280
Total	24	192	
Average	5	40	3,200

IMPORTANCE

Up until 1938 the Richardson ground squirrel was a very serious agricultural pest, and a large amount of public money was spent yearly in an attempt to control its ravages. Since 1938 this animal has been demonstrated as being a serious threat to human health, yet there has been a definite decrease in the amount of money spent on its control. This decrease is due to the fact that the bounty was removed in order to protect school children against a serious infection that is carried by these animals (5).

Such a state of affairs is hardly logical where more money is spent to protect crops than is spent to protect human health, and it is time that serious consideration was given to the ground squirrel situation, and long-term plans for control were laid. These plans should enlist both the Department of Agriculture and Department of Health and should include methods for organized control over all of southern Alberta.

The importance of ground squirrels can be classified under two headings: (1) agriculture and (2) health.

Agricultural Importance

The damage this animal does to field crops and gardens is well known and no further discussion is required.

Health Importance

It is only since 1938 that ground squirrels have assumed a place of importance in regard to human health, and this was brought to light by the activities of the Alberta Rocky Mountain Spotted Fever and Sylvatic Plague Survey. The importance of this animal to human health takes two forms: (1) directly, through the carrying and transmitting of Bubonic (sylvatic) plague infection; and (2) indirectly, through acting as host to spotted fever ticks, *D. andersoni*, which carry and transmit Rocky Mountain spotted fever and Tularaemia (1, 4, 10, 13, 14, 22).

The relationship of these diseases to ground squirrels will be discussed under separate headings.

Sylvatic Plague

This is the Bubonic Plague or Black Death of history, and it is primarily a disease of rodents that can be transmitted to man by the handling of infected animals or by the bite of an infected rodent flea (4, 13, 14, 18, 19, 20).

The causative organism of plague in both man and rodent is *Pasteurella pestis*.

Plague is usually fatal to rodents and often appears amongst them as an epizootic (12, 18, 19). At such times many ground squirrels die bringing about a visible decrease in their numbers. When the animals die their fleas transfer to the first available host for a blood meal and, if they happen to be infected with the plague organism, they will transmit this infection to that particular host. It is possible for these fleas to transfer to, and feed on, man.

Fleas are not the only means whereby the infection is transmitted, for a plague-sick ground squirrel may develop lung complication giving rise to a "pneumonic" type of plague. This type is highly contagious, and is spread from animal to animal, and from animal to man through droplet infection.

Plague in man takes three forms. First a "bubonic" type in which the glands next to the site of infection become enlarged and pus-filled. This type is usually contracted from the bite of an infected flea but it is very seldom fatal. Next a "septicaemic" type in which the plague organism invades the blood stream and causes complications. This type may follow the "bubonic" type or it may be caused by handling infected animals. Quite a few deaths result from this type of infection. The third or

"pneumonic" type is the most serious and is due to the invasion of the lungs by the plague organism. Practically all cases of this type result in death (20).

There is every reason to believe that one death from pneumonic plague contracted through handling infected animals has already occurred in this province (4, 5).

There are at least 2 species of ground squirrel fleas present in this province that can, and do, transmit plague infection (7).

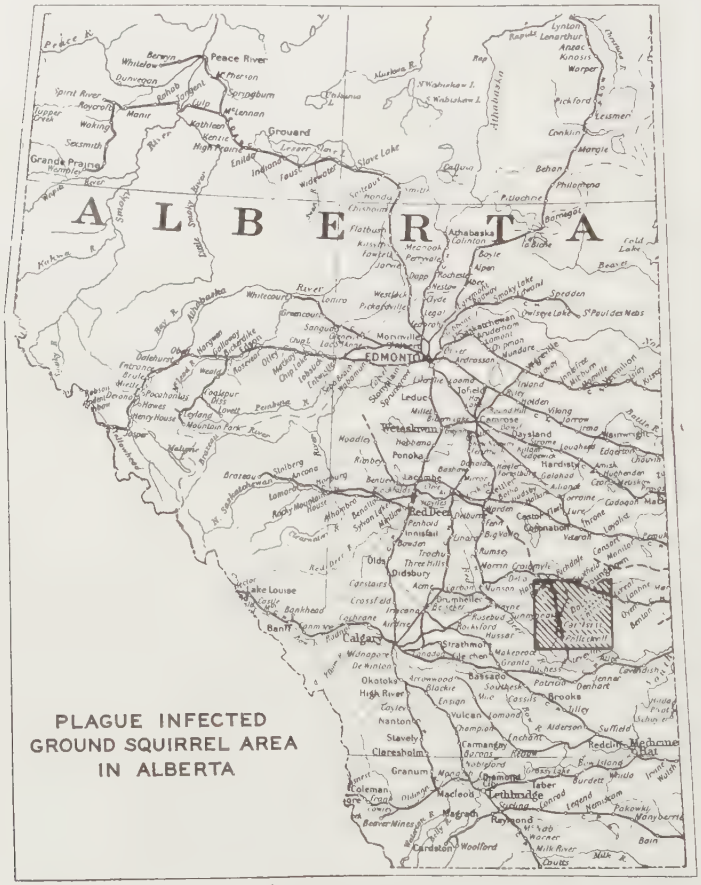

FIGURE 4. Plague Infected Ground Squirrel Area in Alberta.

Besides these there is the human, or cosmopolitan flea[3], *Pulex irritans*, that can also transmit plague under certain conditions.

Plague infected ground squirrels have been found over an area of 2,000 square miles east of Drumheller (Figure 4), and there is good evidence that other plague areas will be discovered in Alberta in the near future (8).

Rocky Mountain Spotted Fever

Rocky Mountain spotted fever is a serious disease of man that is produced by an organism known as *Dermacentroxenus rickettsi*, and is

[3] This species was taken from a badger in the Stanmore plague area in 1940.

transmitted to man through the bite of an infected spotted fever tick *Dermacentor andersoni* (1, 10, 22).

Many species of rodent act as natural reservoirs for this disease but they never suffer any ill effects from it.

The life history of the spotted fever tick is very complicated, and during its development it requires 3 different types of host animal (10, 22). The Richardson ground squirrel acts as a host animal during the second or

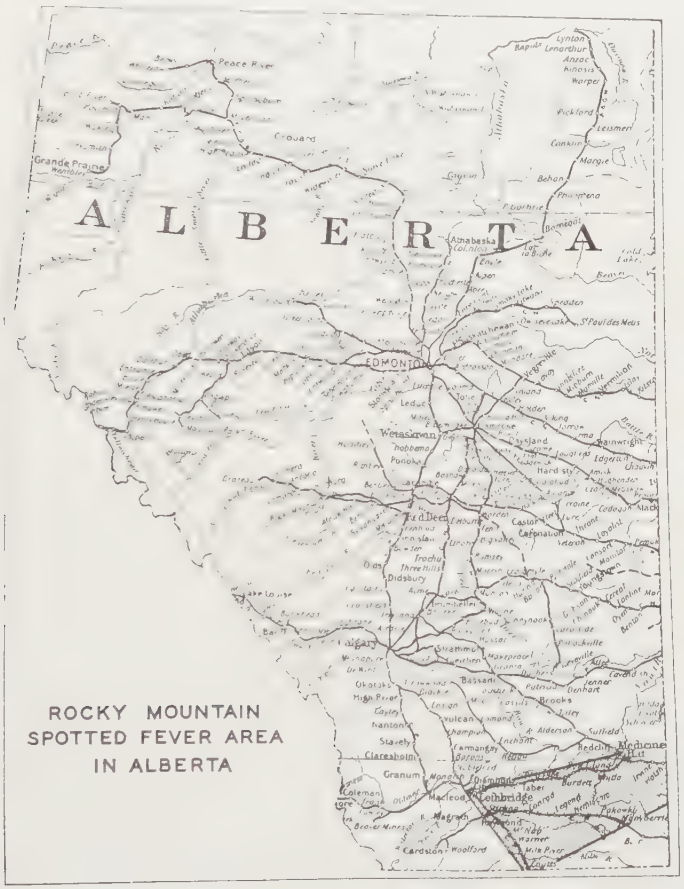

FIGURE 5. Rocky Mountain Spotted Fever Area in Alberta.

nymphal stage of its life cycle. During this stage the nymph tick feeds on the blood of the ground squirrel and if the rodent is carrying the spotted fever organism the tick picks it up, and then during the adult stage it will transmit it to the host animal on which it feeds. As adult ticks often attach to man the infection is then passed on to them, usually with serious consequences, if not death, as the result.

There is a very large area of Rocky Mountain spotted fever infection in the Milk River-Lethbridge-Medicine Hat-Manyberries district (Figure 5), and 6 human cases with 4 deaths have occurred since 1936. The last death occurred during July, 1942 (8).

Tularaemia

This disease, which is commonly called rabbit fever, can be transmitted to man through handling infected animals; by the bite of an infected tick, *D. andersoni*; and by the bite of an infected deer fly, *Chrysops discalis* (22).

The causative organism is *Pasteurella tularense*. This disease has been found in ground squirrels, and in ticks attached to, and feeding on, ground squirrels (8).

Tularaemia is assuming serious proportions in Alberta and it was been demonstrated that ground squirrels play a very important part in its spread through acting as reservoirs for the infection.

Equine Encephalomyelitis

The common name for this disease is "sleeping sickness in horses". It occurs in epidemics and it is believed that about 3 years elapse between outbreaks. The causative organism is suspected as being a virus.

The epidemiology of this infection is not well understood. Some authorities (21, 28) hold to a theory that it is transmitted by mosquitoes.

Gwatkin (16) demonstrated that there are indications of the virus in the brain of the Richardson ground squirrel. The Alberta Sylvatic Plague Survey, from work carried out during 1939, 1941, and 1942, believes that the ground squirrel plays a very important part in epidemiology of this disease.

NEED FOR CONTROL

From the foregoing information it is readily recognizable that a grave need for an effective ground squirrel control campaign now exists. Such a campaign should be organized to cover a large area and should be designed to reduce ground squirrel population to a minimum. It is obvious that such a campaign should have a central office, and it is suggested that the departments of Health and Agriculture assume joint control.

All control campaigns organized in known or suspected plague areas should come under the direct control of the Sylvatic Plague Survey with the work being carried out by the Department of Agriculture. In other areas the campaign would be directed and controlled by the Department of Agriculture.

Provision should be made in the Pest Act for fines, etc. to be levied against those land-owners who refused to co-operate in controlling the ground squirrels on their property during the operation of the campaign.

Control Methods

In various places in the United States and Canada 3 methods of control have been practised successfully. These are poisoning, trapping and fumigation. Each method has certain outstanding features and gives excellent results under ideal conditions, but poisoning is the most common and effective control.

Poisoning

Experience has shown that the use of poisoned grain is the cheapest and most effective method for killing ground squirrels.

Many commercial preparations are on the market as "gopher-poisons". These poisons, before using, are mixed with varying amounts of grain, and most of them have strychnine as the killing agent. Other poisons, such as sodium arsenite, have also been used with good results.

It should always be remembered that any substance poisonous to ground squirrels is also poisonous to other animals and human beings. Care must be taken to keep both the poison and the poisoned grain out of reach of small children and domestic animals.

Poultry and wild game birds cannot be killed with poisoned grain.

Distribution of Poisoned Bait

The best results are obtained if the poisoned bait is put out early in the spring. The time will vary according to the season, but the poison campaign should not be started until at least 90% of the ground squirrels are out of hibernation. In distributing the bait care should be taken to treat all burrows, and in order to make sure it is suggested that each burrow on being treated be marked with a piece of lath. If this method is followed then new burrows can be located as soon as they are made and be treated immediately.

A poison campaign should be well organized and faithfully pursued. Bait should be distributed at least every 2 weeks until it loses its attraction for the animals. This usually happens when the vegetation becomes green.

Poison campaigns should be organized on a large scale, either by districts or municipalities, and every person resident in the campaign area should be encouraged to do everything in his power to control the ground squirrels on his land (11). Vacant lands should be treated as thoroughly as the settled areas, and especial attention should be paid to road allowances.

The Alberta Sylvatic Plague Survey organized and carried out an effective control campaign on 72 sections of land in the Hanna-Stanmore area. This campaign was a model of efficiency, and it is doubtful if a single burrow was missed. In this campaign 15 men were employed and they poisoned approximately 1,280 acres per day (4).

In poisoning cultivated land particular attention should be paid to the headlands for it is in such places that the animals will have their burrows.

Poison Baits

The following types of poison baits have been developed by various governmental agencies and all have yielded good results. Practically all of these baits have strychnine as the killing agent, but there are certain modifications as to mixing and distributing. The following recipes for these baits are listed with comments.

Montana Baits

Spaulding (26) recommends the following types of bait as being both cheap to manufacture and easy to distribute.

1. *Starch-coated Grain*

Wheat or barley	8 quarts
Strychnine (sulphate or alkaloid, powdered)	¾ ounce
Starch	5 tablespoonfuls
Saccharine	½ teaspoonful
Water	1½ pints

Mix the starch to a thin paste free from lumps in a little of the cold water, add the rest of the water, and bring to a boil over a slow fire. Add the saccharine and powdered strychnine. Stir well and pour over the grain. Mix thoroughly until every kernel is evenly coated. Spread on papers to dry. This may be used at once or kept indefinitely in a dry place, but should be labeled as poison. It is strongly recommended that the poisoned grain be prepared some time before it is to be used, so that it may be distributed as soon as the squirrels make their appearance in the spring. Distribute it in the morning, placing about a teaspoonful near the mouth of each occupied burrow.

For the Columbia ground squirrel increase the strychnine to 1 ounce, as this species does not take grain as readily as the other and a stronger poison is needed.

2. *Water-proofed Grain*

Where the poison is to be used while snow is still on the ground, or while the ground is still wet after a rain, the following formula is recommended.

Wheat or barley	8 quarts
Strychnia sulphate	¾ ounce
Water	2 quarts

Dissolve the strychnine in boiling water, cool slightly, and pour over the grain. Allow it to stand until the moisture is all absorbed, stirring occasionally so that it is evenly taken up by the grain. Spread on papers and dry in the sun, *never by fire*, for from 12 to 24 hours. Then heat it over a slow fire for 15 or 20 minutes with about one-half pint of melted beef suet or mutton tallow, stirring constantly to prevent scorching. Allow to cool and it is ready for use as already described.

For Columbia ground squirrels increase the strychnine to 1 ounce.

Comment: This type of bait was very effective but oats were found to be more attractive to ground squirrels. Spaulding believed that the poison bait would kill chickens.

Alberta Baits

Lawton (17) recommended the following types of poison bait, and made the following statement regarding poison baits.

> "Poison should always be placed at least 6 inches into the hole. Do not place or scatter it on the ground around the hole as it may result in the destruction of some of our valuable game or insectivorous birds, or domestic birds and animals."

1. Dissolve 1 ounce of strychnine or sulphate of strychnine in 1 quart of vinegar to which has been added 1 quart of hot water. Stir with a stick until all the strychnine is dissolved, boiling if necessary. Add 1 pound of sugar or 1 pint of molasses and a teaspoonful of oil of anise. Pour the hot solution over half a bushel of wheat and add enough hot water to cover all the wheat. Let the grain stand in the solution for 24 hours, and if any of the solution is then still unabsorbed, add a handful of shorts and stir the whole mixture well. Put 1 tablespoonful of the moist grain well into the entrance of each gopher hole.

2. Mix thoroughly 1 ounce strychnine alkaloid (powdered) and 1 ounce baking soda. Sift this into three-quarters pint of thin, hot starch paste, and stir to a creamy mass. The starch paste is made by dissolving 1 heaping tablespoonful of dry gloss starch in a little cold water, which is then added to three-quarters pint of boiling water. Boil and stir constantly until a clear thin paste is formed. Add one-quarter pint heavy corn syrup and 1 tablespoonful of glycerine, then stir thoroughly. Add one-eighth ounce saccharine and stir thoroughly. Pour this poison solution over 20 quarts of clean oats and mix thoroughly so that each grain is coated. Prepare the poisoned grain 20 to 48 hours before using. For mixing small quantities an ordinary galvanized wash tub is convenient. For larger quantities a tight, smooth box may be used and the mixing done with a spade.

3. To 1 pint of boiling vinegar add 1 ounce of strychnine and stir until dissolved. To this add 2 quarts of water. While boiling add 2 pounds of brown sugar and 1 tablespoonful of oil of anise. Put this mixture into a pail and add cracked grain, handful after handful, constantly stirring, until a juicy mixture is obtained. Put 1 large teaspoonful of this into each gopher hole.

Comment: Mr. Lawton was also under the impression that the poison baits were harmful to chickens. These baits were widely used in this province until superseded by the oat type bait.

Improved Baits

Strickland (27) recommended the following bait as being more effective than poisoned wheat. He points out, however, that this improved bait is more difficult to prepare than poisoned wheat.

Poisoned Oats

Mix one ounce of finely powdered Strychnine Alkaloid and 1 ounce (1 tablespoonful) of baking soda together in a dry form.

Prepare some starch paste as follows: Dissolve 1 heaping tablespoonful of dry gloss starch in a little water. When thoroughly dissolved add enough water to make three-fourths of a pint. Boil and stir constantly till a clear thin paste is formed.

While the starch paste is still hot stir in the mixture of strychnine and baking soda. Stir thoroughly till a creamy mass is formed.

Add one-fourth pint of syrup or molasses, 1 teaspoonful of saccharine, and 1 tablespoonful of glycerine and again stir thoroughly.

Pour this mixture over 20 quarts of good, clean oats, and stir until every kernel is covered with a thin coat of poisoned starch paste.

Distribute in the morning, as directed for poisoned wheat.

Brown (5) recommends a sodium arsenite and oats bait. This bait was used in the 1940 Gopher Control Campaign at Stanmore with very good results. It is a very cheap bait to manufacture.

Sodium Arsenite and Oats

Sodium arsenite	¾ gallon
Oats	1 bushel
Water	1–1½ gallons

Dilute the sodium arsenite in the water, pour the solution over the oats and mix in a mechanical mixer. Mix thoroughly and allow to soak for 12 to 24 hours before using.

The grain may be used in a damp or dry condition. If it is desired to store the poisoned grain for some period of time it should be dried by spreading over a floor before being piled.

Comment: This bait is cheap and easy to mix, and large amounts can be mixed at a time in a mechanical mixer. During the 1940 campaign over 72 sections of land were treated with this bait, and it is estimated that about a 75% kill of animals was achieved. This formula was obtained from O. S. Longman, Alberta Department of Agriculture.

Colorado Formula No. 46

Burnett (9) developed this formula to meet Colorado conditions.

Whole oats	16 quarts
Strychnine (Alkaloid powdered)	1 ounce
Saccharine	⅛ ounce
Baking soda	1 ounce
Fine salt	½ pint
Water	1 pint
Petrolatum oil	¼ pint

Flour to thicken to a creamy paste.

Dissolve strychnine in one-half pint of cold water, then add one-half pint warm water. Stir in soda and saccharine, add salt and oil, put over fire and heat until salt is dissolved, stirring constantly. Remove from fire, stir in flour, making a creamy paste. Pour the poisoned solution over the grain and thoroughly mix. When mixed the grain is ready to use.

Poisoned grain treated with this oil, remains fresh for a greater length of time than grain treated with any other formula we have tried.

Comment: This bait appears to have all the required points essential to cheapness and effectiveness. The oil keeps the bait fresh and attractive for a long period of time.

Iowa Baits

Gunderson and Decker (15) recommend the following baits for ground squirrel control.

1. *Shelled Corn Bait*

Soak shelled corn in solution made by dissolving 1 ounce of strychnine sulphate in 2 quarts of water.

Place poisoned corn where it will be readily available to the ground squirrels.

2. *United States Fish and Wildlife Service Bait*

Mix 1 tablespoonful of laundry starch in one-half teacup of cold water, stir in three-quarters pint of boiling water to make a thin, clear mucilage. Mix 1 ounce of powdered strychnine alkaloid with 1 ounce of powdered bicarbonate of soda and stir the mixture into the hot starch making a smooth creamy paste free from lumps. Stir in one-quarter pint of heavy corn syrup and 1 tablespoonful of glycerine. Apply to 16 quarts of oats and mix thoroughly to coat every kernel.

A quart of poison grain should be enough bait for 40 to 60 holes.

Scatter lightly in teaspoonful quantities around the burrow entrance.

Manitoba Baits

Criddle (11) recommends the following baits for control of ground squirrels.

Strychnine	1 ounce
Molasses	½ pound
Wheat	1 bushel

Dissolve the strychnine in sufficient warm water to soak the grain without leaving a surplus of moisture. When used at once drying is unnecessary, but the grain should be dried quickly if it is to be kept any length of time, otherwise it will become musty or sour.

Strychnine (powder)	¼ ounce
Tallow	10 pounds
Salt	1 ounce

Melt the tallow by heating and add the strychnine and salt. Keep heated until all is thoroughly mixed, then pour into a convenient receptacle to cool and afterwards cut into small lumps for placing in the gopher hole. All such baits should be placed in burrows showing recent signs of being inhabited and in quantity sufficient for one meal.

Trapping

This method is effective in gardens and around buildings. A No. 1 jump or spring trap is usually recommended. The trap should be set in the burrow entrance; bait is not necessary. The trap should be attached by wire to a 3-foot post anchored in the ground. This will prevent the animal from dragging the trap into the burrow. Periodic visits should be made to the traps to prevent undue suffering on the part of the trapped animals, and also to make the traps more effective through re-setting.

Fumigation

Calcium-cyanide, carbon bisulphide and methyl bromide are all gases that have been used very successfully in ground squirrel control. Carbon monoxide has also given very good results but it is difficult to use over large areas.

Calcium-cyanide gas in the form of Cyanogas A, a commercial preparation, is the best known fumigant and it has been used for rodent control in New Zealand, Africa, United States and Canada. Russia also carried out some experimental work but the results have not been obtained. The use of this gas will be considered in detail.

Calcium Cyanide

This gas in the form of Cyanogas has been used very successfully in various places and much information is available as to methods and amounts used. In British Columbia this gas is used extensively for ground squirrel control. The control campaigns in that province are organized as a co-operative endeavour between the farmers and the Department of Agriculture. The department supplies the gas at cost and supervises the campaign. According to a letter from the British Columbia Deputy Minister of Agriculture, excellent control has been achieved.

The Cyanogas, which is in the form of a powder, can be applied to the burrow by means of a spoon or a foot-pump that was specially designed for this work. The amount of dust used varies from 1 to 2 ounces but the majority of workers favour the 2 ounce dose. Sanders (24) working in Saskatchewan recommended that 2 ounces be placed in each burrow by using a long-handled spoon. Wade (30) recommended the same method. The State College of Washington (31) recommends the using of a dusting machine. Tillyard (29) in New Zealand, and workers in South Africa (25) also recommended dusting machines. The British Columbia department of Agriculture uses Cyanogas and dusting machines extensively[4].

Cyanogas is a deadly poison and when it is introduced into the burrow a poisonous gas is liberated from the powder. This gas acts very rapidly and kills the animal, and usually its ectoparasites, in a very short time. The gas is also deadly to human beings.

In using Cyanogas care must be taken to see that all burrow openings except the one being used for the introduction of the gas, are closed, and as soon as the burrow has been treated this opening must also be sealed. The openings can be easily closed by forcing soil into them by means of the boot-heel.

Detailed information regarding the use of Cyanogas has been secured by the Alberta Sylvatic Plague Survey, and it is of the opinion that the cost of a campaign based on Cyanogas is prohibitive, except in cases where human health is threatened, or where small areas, such as gardens and dooryards, are involved.

If it is remembered that on an average there are 5 ground squirrels per acre, and each ground squirrel has an average of 8 burrows, then there will be 40 burrows per acre. If each burrow is to receive 2 ounces it will mean that 80 ounces or 5 pounds of Cyanogas will be required for each acre. As Cyanogas costs approximately 40 cents per pound the cost for the gas alone will run to over $2.00 per acre. To apply the gas efficiently a foot-pump or dusting machine is required and this will cost in the neighbourhood of $8.00. In applying the gas this survey has discovered that one man can only treat a maximum of 8 acres per day.

The use of Cyanogas does have some very decided advantages, the first one being the fact that it is 100% effective in securing a kill. Another advantage is that it kills all of the ectoparasites, those on the animal and those in the debris of the nest. This is the main reason why Cyanogas is recommended as a control agent in plague areas.

[4] Letter.

Carbon Bisulphide

This gas in inflammable and highly explosive so great care must be taken that it is not opened near a fire or where anyone is smoking. Sparks created by the shovel hitting a stone during the closing of a burrow have been known to cause a gas to ignite. As it is a highly volatile gas the container should be kept tightly corked.

The Alberta Sylvatic Plague Survey have not had any experience with this gas. Burnett (9) recommends the following method:

> To use this gas take any absorptive material, such as dry horse-manure, corn cobs, or cotton waste, pour on a large tablespoonful of crude bisulphide, throw it as far as possible down the burrow, quickly close the hole with earth and tamp it with the foot so as to prevent the escape of the gas.

Spaulding (26) recommends the following method:

> A ball of some porous material—dried horse dung or cotton waste answers very well—is saturated with the carbon bisulphide and dropped into the hole, which is immediately plugged with dirt to confine the fumes within the burrow. The best results will be obtained when it is used after a rain, while the ground is still moist, confining the fumes more closely within the burrow and preventing their escape through the porosity of the soil. Moist soil also stops the burrow better than that which is dry and hard.

Methyl Bromide

This gas is a comparatively new one on the market. It has been used very effectively in insect control and has been tried out as a ground squirrel control. This survey has considerable literature on its use but nothing as to its effectiveness as a control.

Carbon Monoxide

This gas is generated by an automobile engine and introduced into the burrow by means of a hose pipe attached to the car exhaust. According to reports the results are very good, but again the survey is not in a position to express an opinion as to its effectiveness.

SUMMARY

1. The Richardson ground squirrel is a native of southern Alberta. It is a prairie-inhabiting rodent that lives in a burrow in the ground and spends the winter in hibernation. It is a vegetarian, feeding on roots and seeds. Only 1 litter, varying from 4 to 9 young, is born a year.

2. Up until 1938 this animal was considered as an agricultural pest only, doing great damage to field crops and gardens. In 1939 it was discovered that it was also a menace to human health in two very important, but widely different ways. The first was that it, and its fleas, were carrying sylvatic (bubonic) plague infection in certain areas in Alberta; and the second was that it was acting as a host for certain stages of the Rocky Mountain spotted fever tick—the transmitter of spotted fever to humans. In 1942 it was discovered that this ground squirrel was also carrying tularaemia—a disease that can be transmitted to man.

3. Prior to 1940 a large sum of public money was spent yearly on poison, and as a bounty, to control this pest. In 1940 this survey had the bounty removed. This step was taken to protect children from the danger of infection. Since 1940 very little money has been spent for control. This is a serious mistake and immediate steps should be taken to organize a definite control with the aim of reducing ground squirrel numbers.

4. It is strongly recommended that an intensive control campaign under the direction of the departments of Health and Agriculture be organized immediately. This campaign should have as its aim the control of ground squirrels throughout southern Alberta generally, but more particularly in the known and suspected plague areas.

5. Methods of control should depend on the degree of population, and whether the area was plague infected or not.

6. Strychnine baits have been used with great success, but there are strong indications that the sodium arsenite and oats bait may be cheaper and just as effective.

ACKNOWLEDGMENTS

All members of the Survey, since its inception, have contributed to the following article by keeping accurate records on all points relating to ground squirrels, and to them many thanks are due. To Mr. Kenneth Walker, Agricultural Fieldman, Special Areas Board, we are extremely grateful for the "gopher" population survey carried out at Stanmore in the fall of 1939. Especial thanks are extended to Dr. F. O. Morrison (now Lecturer in Entomology, Macdonald College) and Dr. G. C. Walkey (now practising in Cadomin, Alberta) for their interest and assistance in establishing the ground squirrel population study while attached to the Survey.

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BOOK REVIEWS

The Parasite Catalogue of the Imperial Parasite Service

The rapid development of scientific and practical work on parasitic and predaceous insects during recent years has created a need for a work of reference indicating the host relations of the entomophagous species and providing in a convenient form a bibliography of the subject. To meet this need the Parasite Catalogue of the Imperial Parasite Service is now being published. This Catalogue was originally compiled on cards as a basis for the work of the staff of the Parasite Service. Its publication was suggested by the delegates to the Imperial Entomological Conference of 1935 and the British Commonwealth Scientific Conference of 1936 in the belief that it would be useful to entomologists everywhere.

The first instalment of the Catalogue, now in course of publication, comprises rearing records for parasites and predators published during the years 1912 to 1935 inclusive, and is estimated to contain about 100,000 citations. The bulk of the records have been taken from the Review of Applied Entomology and papers mentioned therein. When the publication of these records has been completed, it is proposed to publish the records that have appeared since 1935 in a series of supplements, which will be extended to include records anterior to 1912 if the sale of the parts published justifies this further effort.

The Catalogue is divided into four sections which will be issued in the following order:

Section I: Parasite Host Catalogue

Part 1. Arachnida and Coleoptera
2. Dermaptera and Diptera
3. Hemiptera
4. Hymenoptera, Isopoda and Isoptera
5. Lepidoptera A – C
6. Lepidoptera D – G
7. Lepidoptera H – M
8. Lepidoptera N – P
9. Lepidoptera Q – Z
10. Orthoptera, Psocoptera and Thysanoptera.

Section II: Parasite Catalogue

To be issued in parts of convenient size.

Section III: Predator Host Catalogue

Part 1. Arachnida, Coleoptera, Collembola and Diptera
2. Hemiptera
3. Hymenoptera, Isoptera, Lepidoptera, Mollusca, Myriapoda, Neuroptera, Orthoptera and Thysanoptera

Section IV. Predator Catalogue.

To be issued in parts of convenient size.

In the Parasite Host and Predator Host Catalogues, the names of parasites are grouped under the names of their host insects, assembled in Orders. These Catalogues give the name, family, and order of the parasites or predators, the country of record and the bibliographical references. In the section dealing with each Order, the names of host insects are listed according to genera in lexicographical order. Parasites are listed under each host in the same manner. Each part is provided with an index listing all parasites or predators cited under genera in lexicographical order.

In the Parasite and Predator Catalogues host insects are grouped under the names of their parasites and predators, assembled in Orders. These Catalogues give the name, family and order of the parasites, predators and hosts, and the country of record.

In all the parts of the Catalogue, synonyms are connected by cross-references so that hosts, parasites or predators may be found under any name used to designate them in any publication cited.

Though the Catalogue is merely a bibliographical guide to the literature on parasitic and predaceous insects, and therefore reproduces some records which are probably inaccurate, yet it constitutes an indispensable basis for investigations on parasite biology or experiments in biological control. The data on host relations often facilitates the identification of reared species and revisional work of various kinds. The Catalogue also provides a good starting point for the study of the general problems of parasite biology; presenting, in a condensed and convenient form data and references scattered here and there through the immense literature of the subject and unobtainable except at the cost of much time and trouble.

For the sake of economy the Catalogue has been printed by the Multigraph method on stout bond paper. The volumes are approximately Crown 4to. Each part is bound separately in cloth-covered boards. The price of the parts is fixed at present at $2.00 (Canadian) each and will be maintained at as low a level as basic costs permit.

Part 1, listing about 1,000 species of Arachnida and Coleoptera and about 13 species of parasites (pp. ix and 151) and Part 2, listing about 600 species of Dermaptera and Diptera, are now ready.

Parts 3 and 4 will be issued early in 1944 and the remaining parts will follow at short intervals.

Orders for these volumes should be sent to:

The Imperial Parasite Service,

Imperial Institute of Entomology,

228 Dundas St., Belleville, Ontario, Canada.

A Dictionary of the Fungi. By G. C. Ainsworth and G. R. Bisby, Imperial Mycological Institute, Kew, England, 339 pages, 138 figures; published by The Imperial Mycological Institute, Kew, Surrey, England. 1943. Price, $4.60.

Dictionaries and glossaries of various sciences have been published for years, but the book under review may lay claim to being the first mycological dictionary, and as such is a most welcome addition to the literature on fungi. It might be described as a combined terminology of mycology and an alphabetical list of fungus genera with pertinent information, but it is rather more than that, for there are many longer sections dealing with more or less general topics of interest to both mycologists and plant pathologists.

In a foreword, the Director of the Imperial Mycological Institute, Dr. S. P. Wiltshire, points out that the book was originally designed for use by university students, but that as it developed, it became more and more technical. He expresses hope that in its final form, it will prove of service to mycologists in general. He points out the difficulties especially in respect to synonymy encountered in the compilation of the material, due to the lack of unanimity among mycologists. After a careful review of the literature, the authors have tried to reflect current mycological opinion, but are careful to point out in their preface that "by tomorrow, if not today, these decisions may be representative of neither the latest views of the authorities in question, nor the opinion of the reader and the writers."

The list of generic names of fungi includes all of those in use to the end of 1939. Later names are to be given in Supplements to the Review of Applied Mycology. For each genus its systematic position is given, together with the number and distribution of its species. The genera of the bacteria and lichens are excluded. Short accounts follow of the chief families, orders, and classes of fungi, together with explanations of terms used in mycology and illustrated with good line drawings. In addition, some fifty topics, such as, Classification, Genetics of Fungi, Sex, Entomogenous Fungi, Medical Mycology, Industrial Mycology, Plant Pathogenic Fungi, History of Mycology, Biographical Notes, are dealt with. Finally, the authors have appended G. W. Martin's most useful key to the families of fungi, which was originally published in 1941.

The authors explain that special care has been taken to see that the generic and specific names adopted are in agreement with the international Rules of Botanical Nomenclature and that the writing has been done in Basic English as far as possible.

The book is of convenient size, 5 by $7\frac{1}{2}$ inches, the printing leaves nothing to be desired, and as far as one can tell without critical reading, there are very few typographical errors.

The authors have obviously put a tremendous amount of work and thought in the preparation of this book and they are to be congratulated on its excellence. For either the student or the practising mycologist and plant pathologist, it is an invaluable tool and should be within easy reach of all workers in these fields.

F. L. D.